

**DETERMINATION OF SHEAR STRENGTH  
DISTRIBUTIONS FOR GRAPHITE-EPOXY  
COMPOSITE MATERIALS**

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## TABLE OF CONTENTS

	Page
TABLE OF CONTENTS	i
NOMENCLATURE	ii
LIST OF TABLES	iv
LIST OF FIGURES	v
ABSTRACT	vi
INTRODUCTION	1
MATERIALS AND EXPERIMENTAL PROCEDURE	3
TEST RESULTS AND ANALYSIS	7
1. Effect of Span-to-Depth Ratio on Failure Mode	7
2. Effect of Overhang on Failure Mode	8
3. Statistical Analysis Considerations	8
4. Analysis of Panel Data	12
PROPOSED DESIGN PROCEDURE	14
SUMMARY AND CONCLUSIONS	15
ACKNOWLEDGEMENTS	16
REFERENCES	17
APPENDIX A - Determination of Critical Span	81
APPENDIX B - NASA Laminate Description	83
APPENDIX C - Graphical Representation of Shear Strength Data	84
APPENDIX D - Statistical Analysis Program	145
APPENDIX E - Short-Beam Shear Test Fixture	162

## NOMENCLATURE

b	Weibull slope (shape factor)
c <sub>i</sub>	Constant
f	Probability density function
F	Cumulative probability function
I	Area moment of inertia, intercept
M	Bending moment
n	Datum rank
N	Population size
P	Load
r	Span-to-depth ratio
r <sub>crit</sub>	Critical span-to-depth ratio
R(n)	Median rank
s	Specimen span
t	Specimen thickness (depth)
T	Polynomial parameter
w	Specimen width
X	Random variable
x <sub>o</sub>	Weibull minimum value
x <sub>c</sub>	Weibull characteristic value (scale factor)
L	Central displacement
ε	Residual error
μ	Mean value
σ	Tensile stress, standard deviation
σ <sub>m</sub>	Maximum tensile stress
σ <sub>u</sub>	Ultimate tensile strength

$\tau$  Shear stress

$\tau_m$  Maximum shear stress

$\tau_u$  Ultimate shear strength

## LIST OF TABLES

	Page
Table I.      Ratio Determination Data (7:1)	18
Table II.     Ratio Determination Data (6:1)	19
Table III.    Ratio Determination Data (5:1)	20
Table IV.     Ratio Determination Data (4:1)	21
Table V.     Ratio Determination Data (3:1)	22
Table VI.    Ratio and Overhang Determination Data (3.5:1) (0.125" Overhang)	23
Table VII.   Overhang Determination Data (0.420" Overhang)	24
Table VIII.   Overhang Determination Data (0.180" Overhang)	25
Table IX.    Overhang Determination Data (0.0625" Overhang)	26
Table X.     Series 1000 Data	27
Table XI.    Series 2000 Data	31
Table XII.   Series 3000 Data	33
Table XIII.   Series 4000 Data	36
Table XIV.    Series 5000 Data	40
Table XV.    Series 6000 Data	45
Table XVI.   Series 7000 Data	50
Table XVII.   Series 8000 Data	53
Table XVIII.   Series 9000 Data	55
Table XIX.    Series 10000 Data	57
Table XX.    Series 11000 Data	61
Table XXI.   Statistical Data	65
Table XXII.   Series 7000 Random Sampling Data	66
Table XXIII.   Series 9000 Random Sampling Data	69
Table XXIV.   Series 10000 Random Sampling Data	72

## LIST OF FIGURES

	Page
Figure 1. Graphite/Polysulfone Cure Cycle	75
Figure 2. Laminate Lay-up	76
Figure 3. Specimen Dimension Nomenclature	77
Figure 4. Tensile-Shear Strength Comparison at Various Span-to-Depth Ratios	78
Figure 5. Correlation Between Stress and Overhang	78
Figure 6. Theoretical and Physical Shear Stress Distribution	79
Figure 7. Failure Mode at Span-to-Depth Ratio 2:1	80
Figure 8. Failure Mode at Overhang of 0.0625"	80
Figure 9. Loading Rate vs. Displacement Rate Comparison	80

## ABSTRACT

Extensive research has been sponsored and conducted by Langley Research Center, National Aeronautics and Space Administration, to explore the applications of composite materials to the aerospace industry. One of the major problems associated with composites has been the determination of reliability prediction from small samples. As part of their overall program, shear strength tests were conducted on graphite-epoxy composite materials representative of composites currently undergoing service evaluation. Computer analyses were conducted to determine a suitable statistical model for reliability forecasting.

The results of this investigation show that statistical models can be established for predicting reliability levels from small sample sizes. Because of the relatively high cost of graphite-epoxy materials, the ability to reduce the number of specimens needed to establish reliability confidence should result in the more effective use of composites.

## INTRODUCTION

Considerable effort has been expended in recent years to explore the possibility of satisfying the demand for high-strength, high stiffness, lightweight materials for aerospace applications through the use of composite materials. However, predicting the reliability of composite components has been a major problem to the industry. Research in recent years has concentrated on verifying statistical models as to their ability to accurately predict a maximum design strength.

In 1972 the Boeing Company, working under contract (NAS 1-11668) for the National Aeronautics and Space Administration evaluated the properties of graphite-epoxy composite materials submitted by six competing vendors. After evaluation the recommendation was made to NASA to accept materials from three of the vendors for additional testing.

The three recommended vendors were Hercules Incorporated (Systems Group), Union Carbide Corporation (Carbon Products Division), and Whittaker Corporation (Narmco Materials Division). The material was supplied in 3-inch wide pre-impregnated tape and the respective product names were Hercules X3501, Thorne1 300/2544, and Modulite 5209.

After FAA approval had been obtained, Boeing 737 spoilers with graphite-epoxy composite skins were fabricated for in-flight service evaluations. The 737 spoiler was chosen because of its non-critical performance characteristics and because of the aircraft's numerous and short flights which allowed the maximum environmental cycling available. The ultimate goal was to fabricate and evaluate spoilers consisting of 100% composite components. At the same time that the spoilers were fabricated, panels of the material were prepared using identical procedures. These panels provided the material for the specimens evaluated under this project.

The determination of the shear strength distribution and the evaluation of the resulting statistical model for usefulness in establishing reliability levels were the main premises for this paper. The shear strength of the specimens was determined by the short-beam shear test. The short-beam shear test is a three-point loading test which consists essentially of a simply-supported beam with a centrally-applied load. It has been established [1] that the short-beam shear test is the best method

for measuring interlaminar shear, the critical material property of composite materials, in non-wound composites.

When uni-directional composite materials are loaded in tension, the amount of load carried by the matrix is negligible compared to that carried by the fibers resulting in the composite behaving similarly to a homogeneous material. However, it has been shown [3] that compression failure of fiber composites is primarily due to delamination between the fibers and the matrix with subsequent Euler-column buckling of the delaminate. Since graphite-epoxy composites have excellent tensile strength characteristics, the critical structural material property is their compressive strength. Consequently, the strength of a graphite-epoxy component is highly dependent on the ability of the material to resist interlaminar shear.

From the results of the short-beam shear test, two statistical models were fitted to the data and evaluated as to their ability to predict the minimum shear strengths for the various specimen populations.

## MATERIALS AND EXPERIMENTAL PROCEDURE

The graphite-epoxy material received from NASA-Langley consisted of eleven panels 12" x 3" x 25 ply: three panels of Task III [4] material from Union Carbide and Hercules, two panels of Task III material from Narmco, and three panels of Task IV [5] material from Narmco. Two sheets of material were also provided to conduct preliminary tests and to establish testing procedures.

Upon receiving the data from the short-beam shear tests conducted by Boeing some doubt was cast upon the validity of the results. Stoecklin [2] stated that the shear data showed Boeing results to be consistently lower than vendor data, which could have been attributed to a difference in the span-to-depth ratio (Boeing tested at a 5:1 ratio and the vendors used 4:1). This doubt about the span-to-depth ratio led to a complete preliminary analysis of the short-beam shear test before any coupons were prepared from the panels. Three parameters, the span-to-depth ratio, overhang, and strain-rate, were evaluated as to their effect upon failure mode and indicated shear strength.

Since the span-to-depth ratio was thought to be the most critical parameter of the short-beam shear test, it was the first to be evaluated. There are three probable modes of failure for a simply-supported beam with central loading: compressive failure of the top fibers, tensile failure of the bottom fibers, and shear failure along the neutral axis. Since compressive failure usually proceeds by matrix-fiber delamination and subsequent buckling and, since any buckling was total constrained by the load application, the most likely modes of failure were due to tensile and transverse shear stresses. A theoretical calculation using elementary beam theory was performed (Appendix A) with the result that

$$r_{crit} = \frac{\sigma_u}{2\tau_u}$$

where

$r$  = span-to-depth ratio

$\sigma_u$  = ultimate tensile strength

$\tau_u$  = ultimate shear strength.

From the vendor data the tensile strength of the composite was approximately eight times the magnitude of the shear strength and, from the equation, the transition from tensile failure to shear failure should have occurred at a span-to-depth ratio of 4:1.

However, in the calculation the beam material was assumed to be a non-flawed, homogeneous material. Composite materials inherently have multiple internal flaws which have equal probability of being located in any region of the beam volume. For example, if a fatal flaw were located at the outer fibers of the beam and the span-to-depth ratio was near  $r_{crit}$ , the beam could fail in bending even though the ratio implied shear failure. This would result in a low value for the ultimate shear strength of the beam. Therefore, the span-to-depth ratio is dependent upon the general flaw distribution and must be determined experimentally for the specific material being investigated.

The experimental ratios were chosen to insure bending failure on one extreme and shear failure on the other. Sixty specimens were prepared in groups of ten having 1/8" overhang and the following span-to-depth ratios: 7:1, 6:1, 5:1, 4:1, 3:1 and 2:1. The specimens were then loaded to failure and calculations were performed to determine the maximum tensile and shear stresses present at failure. The results as shown in Figure 4 clearly indicate that the transition zone from bending to shear failure occurs at a ratio of 4:1 as calculated.

The results from the specimens with 2:1 ratio showed that unwanted stress effects could also arise from a too-small ratio due to the finite area of load application (Figure 7), therefore, it was decided to use the largest ratio possible which would still insure shear failure. In response to this another set of specimens with ratio 3.5:1 was prepared and tested. These specimens failed in shear and 3.5:1 was the span-to-depth ratio used for further testing.

In addressing the second parameter, the overhang was defined as the length of the specimen which is on the unaffected side of the bottom supports (refer to Figure 3). Elementary beam theory states that the maximum shear stress is constant between the point of load application and the support and that it is zero on the non-loaded side of the support. This stress distribution was graphed in Figure 6a. However, instantaneous

stress changes are physically impossible. A more realistic stress distribution is presented in Figure 6b. Since part of the distribution is on the unloaded side of the support, there was necessary concern about what effect the overhang has on the indicated shear strength of the material. The preferable option was to use the smallest overhang possible to economize on material and, consequently, increase the number of specimen coupons available for testing.

Several overhangs ranging from .0625" to .420" were tested. Ten specimens were prepared for each overhang using a span-to-depth ratio of 3.5:1. Referring to Figure 5 it can be seen that there was zero correlation between the overhang and the maximum bending and shear stress at failure for all values of overhang except 0.0625". The decrease associated with this overhang resulted from the fact that the specimens failed in neither bending or shear but due to matrix rupture at the end supports. Consequently, the smallest overhang without end effects was 0.125" which was the overhang used for the preliminary testing to determine the span-to-depth ratio. If the 0.125" overhang had not been satisfactory, it would have been necessary to repeat the critical ratio determination.

Sufficient material was not available to conduct a conclusive analysis of the effect of the central displacement rate on the shear strength. As such it was assumed that the composite would behave like any other material and would show increased stiffening and strength with increased strain rate. Procedural mistakes during the testing of subsequent specimens resulted several times in high strain rates and the impacted specimens showed a definite increase in failure load which appeared to verify the assumption. A displacement rate of approximately 0.1 inch per minute was chosen to eliminate this false indication of high strength and still minimize the possibility of matrix creep in the specimen.

The sample panels were cut into specimen coupons using a modified, water-cooled diamond saw. It was noted during the fabrication of the specimens that the diamond blade showed no noticeable increase in temperature. The specimens were dimensioned 0.25" wide with a length of 3.5 times the maximum thickness of the panel plus 0.25" for the 0.125" overhang on

each end. After fabrication the specimens were labeled, measured, and remarks were recorded on their condition. Twenty-five specimens each, selected through use of a random number table, were removed from the series 1000, 2000, 3000, and 9000 specimens for extended dehydration and testing not included in this paper.

The short-beam shear testing fixture was designed and machined by Alan Lee and is described in Appendix D. The fixture was mounted on a Tinius-Olson constant-strain universal test machine. In order to insure identical central displacement rates for all specimens the strain rate rheostat control on the test machine was by-passed and a precision resistor was used to set the control current. The resulting circuitry stabilized the machine at a constant crosshead speed of 0.0971 inch per minute.

The span was set in the fixture by lowering the probe into the corresponding recess in the base plate and moving the end supports to the desired position through the use of gage blocks. This procedure resulted in an overall accuracy of  $\pm 0.002"$  in the span. The specimens were then tested in groups of equal span and the failure load was recorded off of a scale accurate to  $\pm 5$  pounds.

## TEST RESULTS AND ANALYSIS

### Effect of Span-to-Depth Ratio on Failure Mode

The results of the span-to-depth ratio determination are presented in Figure 4 and the tabulated data are located in Tables I-VI. It can be seen that the transition in failure modes from bending to shear occurs at a ratio of approximately 4:1. As was to be expected, as the ratio decreased the shear stress at failure stabilized while the bending stress continued to decrease. The data from the tests for a ratio of 2:1 are not presented since the specimens did not fail at any specific load but rather as is shown in Figure 9. To avoid the possibility of this and to insure shear failure a ratio of 3.5:1 was chosen.

It was noted that it was impossible to determine the failure mode of the specimen by examining it after failure. The majority of the specimens exhibited both delamination and fiber disruption after failure. The only way to determine the failure mode was by observation of the actual test. The bending failures proceeded in catastrophic tensile failure of the bottom fibers of the beam with delamination and laminate slippage following immediately. These specimens gave no indication of impending failure and the loading rate was uniform to the point of failure. Since the test machine was a constant-strain machine, a graph of the load versus central displacement of the beam is linear to the point of failure (Figure 9a). Conversely, the shear failures proceeded with delamination and laminate slippage and then, after shear failure, tensile failure of the bottom fibers if the probe was allowed to continue to descend. In the shear failures the loading rate was not constant but declined rapidly upon approaching the failure load (Figure 9b). Associated with the decline in load rate were several sharp sounds prior to delamination.

If the testing machine had been a constant load-rate instead of a constant strain-rate machine, it would have been impossible to determine the difference between bending and shear failure. Also if the tests had not been observed closely, it would have been difficult to determine the failure mode. Therefore, to be certain of the failure mode, the short-beam shear test should be conducted on a constant strain-rate test machine under the supervision of an engineer or experienced technician.

### Effect of Overhang on Failure Mode

The results of the overhang tests are presented in Figure 5 and the data are tabulated in Tables VI-IX. The lack of correlation between the overhang and the stresses at failure was not entirely unexpected in the case of this composite. The extreme brittleness of the epoxy matrix makes the presence of a flaw more critical than the area over which the shear stress acts. Since the specimens had a constant span-to-depth ratio, the probability of a flaw being located in the volume between the supports and causing failure was equal for all the specimens regardless of the amount of overhang. It is open to conjecture as to what effect overhang would have on a composite, such as aluminum-boron, which has a ductile matrix and, consequently, less tendency to propagate a crack produced by a flaw.

### Statistical Analysis Considerations

It was desired to investigate three probability distributions; the normal, log-normal, and Weibull distributions. The primary point of the investigation was not to measure the best fit of the distributions with the data population over the entire range of the population but rather to determine the best fit of the distributions over the minimum shear strengths of the material. The investigation of the log-normal distribution was abandoned during review of statistical literature. Lemon [6] states

...Weibull has shown that to make a significant distinction between the log-normal distribution and Weibull distribution, both being of apparent similarity, a sample size larger than 1000 would be required.

Since the sample sizes were around 100 specimens, it was decided to emphasize the Weibull distribution because of its greater versatility.

The normal or Gaussian distribution function is commonly used for statistical analysis of empirical data. The normal distribution has the density function

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\mu)^2/2\sigma^2}, -\infty < x < \infty$$

and cumulative function

$$F(X) = 1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^X e^{-(x-\mu)^2/2\sigma^2} dx$$

where

$$\mu = \frac{1}{N} \sum_{i=1}^n x_i \quad (\text{mean})$$

and

$$\sigma = \left[ \frac{1}{N-1} \sum_{i=1}^n (x_i - \mu)^2 \right]^{1/2}$$

(standard deviation)

Much of the data which we observe can be said to be normally distributed as a first approximation; however, serious error can be made by assuming that a normal distribution strictly applies to a particular physical situation. Discrepancies are most readily encountered when applying the normal distribution to extreme value analysis. This is the most critical area in the reliability of a design and makes it necessary to use a probability function which can predict the minimum values of a data population.

A distribution which is especially suited for this is the Weibull distribution function proposed by a contemporary Swedish research engineer, W. Weibull. The Weibull distribution has the density function

$$f(x) = \frac{b}{x_c} \left( \frac{x-x_o}{x_c} \right)^{b-1} \exp \left[ - \left( \frac{x-x_o}{x_c} \right)^b \right]$$

where

$$x > x_o, x_c > 0, b > 0$$

and

$x_o$  = minimum value

$x_c$  = characteristic value (scale factor)

$b$  = Weibull slope (shape factor)

The cumulative Weibull distribution is

$$F(x) = 1 - \exp \left[ - \left( \frac{x-x_o}{x_c} \right)^b \right].$$

The characteristic life is a measure of the central tendency and is analogous to the mean of the normal distribution, and the Weibull slope is a measure of the data dispersion (less dispersion with larger b) and is analogous to the standard deviation.

Since in static testing the concept of a minimum strength other than zero cannot be defined, the value of  $X_0$  is taken as zero which leads to the two parameter form of the Weibull

$$f(x) = \frac{b}{X_c} \left(\frac{x}{X_c}\right)^{b-1} \exp\left[-\left(\frac{x}{X_c}\right)^b\right]$$

and

$$F(x) = 1 - \exp\left[-\left(\frac{x}{X_c}\right)^b\right].$$

The calculation of the shape and scale factors cannot be performed by elementary operations as is the case for the normal distribution. By taking natural logarithms twice, the cumulative function is transformed into

$$\ln \ln \left[ \frac{1}{1-F(x)} \right] = b \ln x - b \ln X_c.$$

Since b and  $X_c$  are constants for a given population, the last equation has the form of a straight line with slope b and intercept  $-b \ln X_c$ . By replacing F(x) with R(n) where R(n) is the median rank associated with the nth datum,

$$\ln \ln \left[ \frac{1}{1-R(n)} \right] \text{ vs. } \ln x_n$$

may be plotted, and, using a linear least squares fit, the slope and the intercept of the plot can be calculated. The calculated slope is, of course, the shape factor associated with the data population and the scale factor can be found through

$$X_c = \exp \left[ \frac{l}{b} \right]$$

where l is the calculated intercept.

The median rank

$$R(n) = \frac{n-0.3}{N+0.4}$$

was chosen to rank the sorted data since it is just as likely to err on the high side as on the low side.

For visual comparison of the two distributions it was desirable to smooth out the frequency graphs. Since the actual maximum shear stress has equal probability of having any value within the interval defined by the recorded value plus or minus the error limits, a moving average was taken over the error limits and the density and cumulative functions were fitted to the smoothed data by using calculated parameters and equating areas under the frequency polygon and under the fitted function. However, for the extreme value analysis greater accuracy was desired. This was simple for the Weibull distribution since it is a basic exponential function but difficult for the normal distribution due to the integral form of the relationship. Therefore, the following approximating polynomial [8] was used

$$F(X) = 1/2(1+C_1T+C_2T^2+C_3T^3+C_4T^4)^{-4} + \epsilon(T)$$

where

$$T = \left| \frac{X-\mu}{\sigma} \right|$$

$$|\epsilon(T)| < 2.5 \times 10^{-4}$$

$$C_1 = 0.196854$$

$$C_2 = 0.115194$$

$$C_3 = 0.000344$$

$$C_4 = 0.019527.$$

The resulting curves were then compared against the shear stresses of the first 15% of each population.

To compare the two cumulative distributions with the actual data, the average calculated value for each 50 psi interval was subtracted from the actual cumulative data frequencies. The residual  $\epsilon$  for each interval was taken to second, third, and fourth power and summed over the 15% range. The sum of the  $\epsilon$ 's compared deviations between the areas

underneath the function and the frequency polygon and the sum of the  $\epsilon$ 's squared compared deviations between the function and the frequency polygon. The sum of the  $\epsilon$ 's to the third and fourth power gave the same indications respectively but emphasized the larger residuals.

To verify the ability of the distributions to predict the minimum value of the material a program was constructed which randomly selected small samples out of the parent population. Normal and Weibull distributions were calculated for this sample and the resulting functions were solved for the shear stress which 99.9% of specimens should statistically survive. These values were compared to the minimum value of the parent population and verification was based on this criterion.

#### Analysis of Panel Data

The graphical comparisons of the Normal and Weibull distributions with the empirical data are presented in Appendix C. Although not much distinction can be made between the Normal and the Weibull distribution when compared to the entire population, the comparison with the lower extreme values immediately shows that the Weibull distribution describes the empirical results better than the Normal distribution. Even when neither distribution describes the data accurately (Series 3000 and 5000), the Weibull distribution always predicts a greater probability of failure than the Normal distribution. This conservative nature of the Weibull distribution is desirable for reliability analysis.

When the results are grouped by vendor and task number, it can be seen that the measures of central tendency are consistent, within the  $\pm 2\%$  error limits in calculated shear strength, for the various groupings. The only exception to this is the Series 3000 data which is explained by the fact that the vacuum bag broke during the fabrication of the panel resulting in a different composition of the material. The consistency validates the ability to fabricate a composite with constant material properties. The TASK IV specimens are especially meaningful in this respect since they were fabricated out of different lots of pre-impregnated tape.

Since the Task IV specimens represent the present "state-of-the-art" in graphite-epoxy composite fabrication, a random data sampling process

was carried out from the parent population. This was done with the Series 7000, 9000, and 10000 specimen populations starting with 50% sampling down to 5%. The desire was to determine if the Weibull distribution function could predict consistent reliability levels with a small population.

For Series 7000, 7250 psi was the 99.9% reliability value predicted by the entire population and minimum specimen strength was 8735 psi. Reliability levels found from the random sampling technique were a low of 6100 psi for a sample size of 6 and a high of 7900 psi for a sample size of 12. 8050 psi was the predicted 99.9% reliability level and 8764 psi the minimum specimen shear strength for the Series 9000 population. Levels ranged from a low of 6700 psi for a sample size of 9 to a high of 9150 psi for size 8. The Series 10000 population predicted a reliability level of 8600 psi and had a minimum shear strength of 9722 psi. The sampling predictions ranged from a high of 9600 psi for 19 specimens to a low of 7450 psi for 16 specimens. By reducing the population size through the random sampling technique, it can be seen (Tables XXII-XXIV) that failure levels are fairly constant and vary only approximately by  $\pm$  10% at a sample size of 10 specimens.

## PROPOSED DESIGN PROCEDURE

Several steps are involved in developing a reliability model for composite materials. The first step must be to establish a sound testing procedure. Next is to conduct the actual sample testing which must be adequately supervised. After calculating the Weibull parameters, the desired reliability level can be found.

The most important concept is to establish a sound and comprehensive testing procedure. When evaluating composite materials, it is necessary to insure that the procedure being used actually determines the desired material properties. The short-beam shear tests conducted by Boeing showed that mis-evaluations can occur rather easily, resulting in inaccurate values and waste of material at the design stage. The least that should be done is to establish a mathematical model but, if feasible, to actually conduct some preliminary testing. By varying the test parameters, some indication can be gained of the validity of the test and of an approximate optimal value for the test parameters. When dealing with materials as analytical complex as composites, this procedure becomes a necessity so as not to arrive at erroneous results.

The most important point while conducting the actual materials testing is to insure that whoever is conducting the testing can recognize failure modes for the particular composite being evaluated. Someone should be present to terminate the testing if the specimens are failing in a mode other than that desired. Even if the first step is conducted thoroughly, the possibility still exists that not all of the testing parameters have been identified and, considering the expense of advance composites, testing needs to be terminated immediately upon obtaining questionable results.

It has been shown that the two-parameter Weibull distribution function does an excellent job of predicting extreme value distributions. The best feature of the Weibull is that it always tends to be conservative compared to the Normal distribution which is an important asset for any statistical model used in design engineering.

## SUMMARY AND CONCLUSIONS

The results of this investigation to study the possibility of arriving at an accurate reliability model for graphite-epoxy composite materials can be summarized as follows:

1. The variables of the testing procedure in conjunction with the type of composite being tested can have a marked influence upon the validity of the results.
2. The lack of expert supervision during testing can easily result in erroneous results and waste of expensive material.
3. The Weibull distribution function is an excellent statistical tool for evaluating extreme values of empirical populations.

Although the author realizes that inexpensive evaluation of advanced composites structures, due to their complex nature, lies in the future, the performance of the Weibull distribution function in making accurate predictions from small samples should reduce the number of actual assemblies needed at present to insure reliability.

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Table I. Ratio Determination Data (7:1)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
1	.240	.128	445	152100	10864
2	.238	.128	445	153400	10956
3	.249	.128	445	146600	10472
4	.257	.127	480	154400	11030
5	.236	.128	425	147700	10552
6	.252	.128	460	149700	10696
7	.252	.128	460	149700	10696
8	.234	.127	445	157200	11231
9	.238	.128	405	139600	9971
10	.256	.128	455	145800	10414

$$\sigma_{ave} = 149600 \text{ psi}$$

$$\tau_{ave} = 10688 \text{ psi}$$

Table II. Ratio Determination Data (6:1)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
11	.254	.127	430	119900	9998
12	.236	.127	480	144100	12011
13	.235	.127	490	147800	12314
14	.250	.126	530	151400	12619
15	.244	.128	495	142600	11887
16	.271	.127	485	126800	10569
17	.263	.128	520	139000	11585
18	.259	.127	425	116300	9691
19	.254	.127	540	150700	12555
20	.249	.126	510	146300	12192

$$\sigma_{ave} = 138500 \text{ psi}$$

$$\tau_{ave} = 11542 \text{ psi}$$

Table III. Ratio Determination Data (5:1)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
21	.236	.126	500	126100	12611
22	.250	.127	570	134600	13465
23	.260	.127	580	131700	13174
24	.243	.126	535	131100	13105
25	.237	.126	485	121800	12181
26	.239	.126	515	128300	12826
27	.232	.127	580	147600	14764
28	.253	.127	545	127200	12721
29	.235	.127	545	137000	13696
30	.241	.127	535	128600	12865

$$\sigma_{ave} = 131400 \text{ psi}$$

$$\tau_{ave} = 13141 \text{ psi}$$

Table IV. Ratio Determination Data (4:1)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
31	.259	.128	585	105900	13234
32	.241	.128	590	114800	14345
33	.232	.128	575	116200	14522
34	.242	.128	615	119100	14891
35	.238	.128	550	108300	13541
36	.235	.129	600	118800	14844
37	.235	.128	610	121700	14209
38	.250	.129	625	116300	14535
39	.246	.128	645	122900	15363
40	.249	.129	620	115800	14477

$$\sigma_{ave} = 116000 \text{ psi}$$

$$\tau_{ave} = 14496 \text{ psi}$$

Table V. Ratio Determination Data (3:1)

Specimen Number	Width (in)	Thickness (in)	Load (1bs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
41	.244	.127	620	90000	15006
42	.244	.128	600	86400	14408
43	.232	.127	615	93900	15655
44	.231	.127	590	90500	15083
45	.263	.128	660	88200	14704
46	.239	.128	575	84600	14097
47	.254	.127	620	86500	14415
48	.251	.127	700	98800	16470
49	.246	.128	545	77900	12981
50	.237	.127	640	95700	15947

$$\sigma_{ave} = 89300 \text{ psi}$$

$$\tau_{ave} = 14877 \text{ psi}$$

Table VI. Ratio and Overhang Determination Data (3.5:1)  
(0.125" Overhang)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
51	.250	.128	600	98400	14063
52	.237	.128	575	99500	14216
53	.238	.128	575	99100	14156
54	.238	.128	640	110300	15756
55	.233	.128	535	94200	13454
56	.243	.128	595	100400	14347
57	.266	.128	650	100200	14318
58	.240	.128	620	106000	15137
59	.230	.128	575	102500	14648
60	.241	.128	590	100400	14345

$$\sigma_{ave} = 101100 \text{ psi}$$

$$\tau_{ave} = 14444 \text{ psi}$$

Table VII. Overhang Determination Data  
(0.480" Overhang)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
61	.251	.128	645	105400	15057
62	.238	.128	615	106000	15141
63	.246	.128	605	100900	14410
64	.236	.128	575	99900	14276
65	.246	.128	630	105000	15006
66	.238	.128	555	95600	13664
67	.234	.128	585	102500	14648
68	.239	.128	580	99500	14219
69	.240	.128	555	94800	13550
70	.247	.128	560	93000	13284

$$\sigma_{ave} = 100300 \text{ psi}$$

$$\tau_{ave} = 14326 \text{ psi}$$

Table VIII. Overhang Determination Data  
(0.180" Overhang)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
71	.245	.128	620	103800	14828
72	.238	.128	650	112000	16002
73	.247	.128	630	104600	14945
74	.233	.128	580	102100	14586
75	.253	.128	605	98100	14012
76	.259	.128	660	104500	14931
77	.241	.128	645	109800	15682
78	.239	.128	555	95200	13606
79	.226	.128	570	103400	14778
80	.230	.128	535	95400	13629

$$\sigma_{ave} = 102900 \text{ psi}$$

$$\tau_{ave} = 14700 \text{ psi}$$

Table IX. Overhang Determination Data  
(0.0625" Overhang)

Specimen Number	Width (in)	Thickness (in)	Load (lbs)	$\sigma_{max}$ (psi)	$\tau_{max}$ (psi)
81	.259	.128	560	88700	12669
82	.256	.128	535	85700	12245
83	.250	.128	560	91900	13125
84	.256	.128	645	103300	14763
85	.250	.128	555	91100	13008
86	.258	.128	600	95400	13626
87	.255	.128	580	93300	13327
88	.259	.128	620	98200	14026
89	.258	.128	605	96200	13740
90	.264	.128	595	92400	13206

$$\sigma_{ave} = 93600 \text{ psi}$$

$$\tau_{ave} = 13374 \text{ psi}$$

Table X. Series 1000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
1002	.7480	.2495	.1385	685	14867
1003	.7425	.2500	.1395	645	13871
1004	.7440	.2495	.1420	675	14289
1006	.7465	.2500	.1430	695	14580
1009	.7435	.2495	.1435	725	15187
1010	.7445	.2500	.1430	695	14580
1015	.7465	.2500	.1340	660	14776
1017	.7450	.2505	.1360	710	15631
1019	.7440	.2490	.1445	700	14591
1020	.7465	.2500	.1455	695	14330
1021	.7410	.2505	.1450	725	14970
1024	.7460	.2505	.1460	715	14662
1025	.7405	.2505	.1480	690	13959
1028	.7360	.2500	.1430	675	14161
1029	.7415	.2510	.1430	545	12433
1030	.7480	.2500	.1450	650	13448
1031	.7465	.2495	.1430	655	13769
1032	.7435	.2495	.1395	595	12821
1033	.7460	.2500	.1405	500	10676
1034	.7445	.2495	.1465	705	14466
1036	.7470	.2500	.1405	645	13772
1038	.7430	.2495	.1340	625	14021
1040	.7455	.2510	.1465	695	14195
1043	.7430	.2500	.1465	695	14232
1044	.7450	.2495	.1465	675	13850
1045	.7460	.2495	.1440	650	13569
1046	.7435	.2495	.1415	645	13702
1047	.7435	.2485	.1395	645	13955
1048	.7455	.2500	.1380	550	11957
1049	.7430	.2510	.1450	710	14631
1050	.7400	.2495	.1450	685	14201

Table X. Series 1000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
1051	.7455	.2505	.1430	675	14133
1052	.7415	.2505	.1440	680	14138
1053	.7440	.2500	.1470	700	14286
1054	.7450	.2485	.1445	680	14203
1055	.7365	.2490	.1430	670	14112
1057	.7455	.2500	.1420	670	14155
1059	.7420	.2495	.1410	665	14177
1060	.7430	.2475	.1340	565	12777
1061	.7480	.2480	.1320	685	15694
1064	.7375	.2500	.1420	660	13944
1065	.7440	.2520	.1430	650	13528
1067	.7450	.2500	.1450	645	13345
1068	.7440	.2490	.1425	670	14162
1069	.7430	.2490	.1460	710	14648
1071	.7450	.2495	.1360	670	14809
1072	.7445	.2495	.1435	680	14245
1074	.7450	.2490	.1340	640	14386
1075	.7455	.2500	.1445	655	13599
1076	.7440	.2505	.1440	730	15178
1077	.7460	.2500	.1480	705	14291
1078	.7450	.2480	.1330	645	14666
1079	.7460	.2510	.1470	665	13517
1080	.7430	.2510	.1430	605	12642
1082	.7475	.2490	.1420	680	14424
1083	.7460	.2490	.1425	700	14796
1084	.7445	.2500	.1440	690	14375
1085	.7435	.2490	.1410	675	14419
1086	.7400	.2500	.1465	725	14846
1087	.7415	.2480	.1420	660	14056
1088	.7430	.2470	.1440	710	14971

Table X. Series 1000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
1090	.7390	.2505	.1460	690	14150
1091	.7445	.2490	.1450	675	14022
1092	.7455	.2495	.1460	670	13795
1095	.7405	.2500	.1470	655	13367
1096	.7425	.2490	.1420	690	14636
1097	.7450	.2485	.1445	665	13890
1099	.7440	.2500	.1445	655	13599
1100	.7435	.2505	.1430	690	14447
1103	.7445	.2505	.1430	685	14342
1104	.7445	.2505	.1480	710	14363
1107	.7340	.2500	.1480	680	13784
1108	.7430	.2505	.1440	690	14346
1109	.7445	.2510	.1435	695	14472
1111	.7445	.2490	.1380	660	14405
1112	.7480	.2550	.1390	670	14177
1113	.7455	.2505	.1445	700	14504
1115	.7425	.2500	.1420	675	14261
1117	.7430	.2450	.1360	690	15531
1119	.7405	.2495	.1450	680	14097
1121	.7460	.2495	.1400	620	13312
1124	.7435	.2500	.1340	525	11754
1126	.7410	.2485	.1440	685	14357
1129	.7425	.2510	.1445	720	14889
1130	.7435	.2495	.1460	650	13383
1131	.7440	.2490	.1430	615	12928
1132	.7435	.2500	.1430	670	14056
1134	.7460	.2500	.1450	690	14276
1135	.7440	.2470	.1350	665	14957
1136	.7440	.2310	.1420	665	15205
1137	.7445	.2510	.1440	660	13695

Table X. Series 1000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
1138	.7445	.2500	.1435	705	14739
1141	.7455	.2500	.1440	720	15000
1142	.7450	.2490	.1460	735	15163
1144	.7455	.2520	.1440	600	12401
1145	.7440	.2500	.1440	665	13854
1147	.7445	.2510	.1430	675	14104
1148	.7380	.2500	.1430	735	15420
1149	.7440	.2530	.1430	650	13475
1150	.7440	.2480	.1450	670	13974

Table XI. Series 2000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)	Remarks
2001	.8445	.2575	.1657	625	10986	
2004	.8445	.2530	.1580	580	10882	Flaw
2005	.8445	.2585	.1615	615	11048	
2009	.8455	.2575	.1500	515	10000	
2012	.8445	.2570	.1610	585	10604	Flaw
2015	.845	.2575	.1633	620	11058	
2016	.845	.2595	.1650	635	11123	
2017	.8435	.2585	.1657	580	10156	
2018	.845	.255	.1660	610	10808	
2020	.8437	.258	.1678	625	10828	Flaw
2021	.8443	.2555	.1713	635	10881	Flaw
2022	.8433	.2583	.1700	635	10846	Flaw
2023	.845	.2585	.1685	625	10762	
2024	.8445	.2583	.1690	600	10309	
2027	.8465	.2585	.1663	575	10032	
2036	.8462	.259	.1675	610	10546	
2037	.8465	.258	.1673	615	10686	
2038	.8466	.259	.1730	555	9290	Flaw
2039	.8460	.2587	.1730	625	10474	
2040	.8468	.259	.1680	630	10859	
2043	.8464	.259	.1695	575	9823	Flaw
2044	.8461	.2555	.1740	625	10544	Flaw
2046	.8456	.258	.1690	635	10923	Flaw
2049	.8458	.2567	.1720	625	10617	Flaw
2050	.8458	.2555	.1675	615	10778	
2051	.8461	.258	.1650	610	10747	Flaw
2052	.8457	.2563	.1635	575	10291	
2053	.8456	.2570	.1680	575	9988	
2064	.8461	.2585	.1730	640	10733	Flaw
2065	.8468	.2590	.1725	605	10156	

Table XI. Series 2000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)	Remarks
2066	.8454	.2585	.1720	630	10627	
2067	.8460	.2593	.1728	630	10545	Flaw
2068	.8457	.2583	.1718	630	10648	
2069	.8465	.2585	.1705	580	9870	
2070	.8460	.2595	.1710	555	9380	Flaw
2071	.8455	.2575	.1700	600	10280	Flaw
2073	.8477	.2578	.1700	620	10623	Flaw
2074	.8467	.2573	.1695	600	10318	
2076	.8470	.2565	.1655	600	10601	Flaw
2077	.8480	.2565	.1650	590	10455	Flaw
2081	.8455	.2565	.1715	640	10912	
2084	.8457	.2583	.1660	590	10320	Flaw
2085	.8473	.2575	.1652	630	11107	
2087	.8477	.2535	.1665	600	10662	
2088	.8475	.2575	.1685	630	10890	
2091	.8470	.257	.1705	615	10526	
2092	.8468	.2565	.1665	635	11152	
2093	.8445	.258	.1710	625	10625	
2094	.8470	.258	.1733	635	10652	
2095	.8435	.258	.1725	630	10617	
2096	.8460	.258	.1720	650	10986	
2098	.8465	.2535	.1730	605	10346	Flaw
2099	.8460	.257	.1690	630	10879	
2101	.8460	.2565	.1658	600	10581	Flaw
2102	.8455	.254	.1625	610	11084	

Table XII. Series 3000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
3001	.7795	.2510	.1405	555	11803
3002	.7795	.2500	.1420	645	13627
3003	.7800	.2535	.1350	450	9862
3004	.7800	.2490	.1450	620	12879
3006	.7815	.2500	.1430	610	12797
3007	.7820	.2450	.1485	580	11956
3008	.7810	.2490	.1430	660	13902
3009	.7805	.2480	.1445	565	11825
3010	.7810	.2470	.1445	605	12713
3011	.7805	.2450	.1420	600	12935
3012	.7805	.2510	.1435	635	13222
3013	.7800	.2495	.1425	640	13501
3015	.7810	.2495	.1430	625	13138
3016	.7810	.2480	.1405	570	12269
3017	.7800	.2490	.1465	595	12233
3019	.7810	.2520	.1485	630	12626
3021	.7810	.2510	.1500	685	13645
3023	.7800	.2470	.1445	600	12608
3024	.7810	.2520	.1445	615	12667
3027	.7825	.2510	.1495	670	13391
3028	.7830	.2490	.1525	520	10271
3029	.7815	.2500	.1470	570	11633
3030	.7825	.2520	.1490	690	13782
3036	.7805	.2500	.1365	405	8901
3039	.7805	.2478	.1425	640	13637
3040	.7755	.2510	.1445	650	13441
3042	.7815	.2520	.1460	675	13760
3043	.7805	.2500	.1460	615	12637
3044	.7810	.2490	.1490	595	12028
3048	.7815	.2515	.1475	555	11221

Table XII. Series 3000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
3050	.7805	.2500	.1480	600	12162
3051	.7805	.2480	.1370	395	8719
3052	.7800	.2500	.1425	640	13474
3054	.7800	.2490	.1465	600	12336
3055	.7800	.2520	.1425	600	12531
3056	.7805	.2470	.1435	575	12167
3057	.7815	.2460	.1475	590	12195
3058	.7805	.2480	.1480	590	12056
3059	.7815	.2520	.1480	600	12066
3063	.7810	.2535	.1440	640	13149
3064	.7810	.2515	.1410	660	13959
3066	.7810	.2500	.1435	590	12334
3067	.7815	.2450	.1460	575	12056
3068	.7810	.2490	.1410	595	12710
3069	.7810	.2525	.1440	690	14233
3072	.7810	.2500	.1435	580	12125
3073	.7800	.2510	.1480	590	11912
3074	.7800	.2500	.1425	635	13368
3075	.7765	.2520	.1520	655	12825
3076	.7790	.2510	.1430	540	11284
3079	.7770	.2520	.1475	700	14124
3080	.7820	.2500	.1430	635	13322
3081	.7800	.2520	.1445	460	9474
3082	.7810	.2490	.1430	600	12638
3084	.7805	.2520	.1420	605	12680
3085	.7810	.2480	.1435	660	13909
3086	.7820	.2515	.1475	585	11827
3088	.7810	.2515	.1415	640	13488
3089	.7800	.2525	.1435	645	13351
3090	.7795	.2510	.1425	630	13210

Table XII. Series 3000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
3092	.7805	.2530	.1445	585	12001
3096	.7815	.2485	.1445	675	14098
3097	.7810	.2470	.1415	675	14485
3099	.7815	.2480	.1410	635	13620
3112	.7810	.2470	.1445	590	12398
3115	.7810	.2500	.1415	570	12085
3116	.7810	.2510	.1450	700	14425
3117	.7815	.2530	.1440	670	13793
3118	.7810	.2510	.1475	605	12256
3122	.7800	.2505	.1440	650	13515
3124	.7810	.2475	.1455	605	12600
3125	.7820	.2515	.1440	620	12840
3127	.7810	.2510	.1425	675	14154
3128	.7810	.2470	.1475	660	13587
3131	.7820	.2520	.1435	610	12651
3132	.7815	.2520	.1455	660	13500
3133	.7820	.2530	.1500	575	11364
3134	.7805	.2415	.1365	390	8873
3135	.7765	.2520	.1440	650	13434
3137	.7820	.2510	.1425	695	14573

Table XIII. Series 4000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
4001	.7880	.2525	.1360	610	13323
4002	.7875	.2545	.1355	685	14245
4005	.7875	.2535	.1420	615	12814
4008	.7880	.2505	.1360	635	13979
4009	.7870	.2490	.1345	645	14444
4011	.7880	.2535	.1455	625	12709
4012	.7880	.2525	.1350	615	13531
4013	.7885	.2520	.1445	630	12976
4014	.7870	.2500	.1400	605	12964
4015	.7880	.2520	.1355	650	14277
4016	.7880	.2520	.1325	575	12916
4018	.7860	.2525	.1345	670	14796
4020	.7885	.2545	.1355	665	14463
4021	.7865	.2515	.1345	610	13525
4022	.7880	.2540	.1335	670	14819
4023	.7885	.2540	.1330	585	12988
4024	.7830	.2545	.1380	670	14308
4025	.7875	.2535	.1355	600	13101
4026	.7890	.2525	.1310	610	13831
4027	.7895	.2555	.1275	595	13699
4029	.7850	.2490	.1440	645	13491
4030	.7890	.2550	.1355	620	13458
4032	.7885	.2530	.1350	660	14493
4035	.7830	.2555	.1435	685	14012
4036	.7880	.2525	.1315	620	14004
4037	.7875	.2490	.1305	620	14426
4038	.7855	.2435	.1330	635	14706
4039	.7885	.2490	.1400	615	13231
4040	.7885	.2525	.1355	625	13701
4042	.7880	.2515	.1340	635	14132

Table XIII. Series 4000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
4043	.7895	.2515	.1315	640	14514
7044	.7865	.2520	.1360	615	13459
4045	.7860	.2565	.1405	680	14152
4046	.7865	.2490	.1355	620	13782
4047	.7840	.2520	.1350	635	13999
4048	.7865	.2500	.1320	575	13068
4049	.7880	.2530	.1245	565	13453
4050	.7875	.2550	.1365	620	13359
4051	.7880	.2535	.1345	585	12868
4052	.7865	.2500	.1320	620	14091
4053	.7890	.2500	.1335	595	13371
4054	.7865	.2545	.1355	630	13702
4055	.7870	.2545	.1350	660	14407
4056	.7865	.2525	.1340	640	14186
4057	.7890	.2525	.1320	600	13501
4058	.7845	.2515	.1430	635	13242
4059	.7880	.2535	.1335	640	14183
4060	.7835	.2555	.1355	625	13540
4061	.7850	.2550	.1365	650	14006
4062	.7880	.2550	.1365	685	14760
4063	.7870	.2475	.1425	650	13822
4065	.7885	.2550	.1440	675	13787
4066	.7850	.2525	.1375	665	14365
4067	.7865	.2500	.1350	670	14889
4068	.7875	.2530	.1450	685	14004
4069	.7880	.2530	.1345	680	14987
4071	.7880	.2540	.1330	600	13321
4072	.7860	.2525	.1340	660	14630
4073	.7875	.2560	.1305	610	13694
4074	.7890	.2490	.1335	650	14665

Table XIII. Series 4000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
4075	.7880	.2540	.1450	620	12626
4076	.7840	.2530	.1350	580	12736
4077	.7860	.2510	.1340	640	14271
4078	.7845	.2520	.1350	645	14220
4079	.7875	.2505	.1300	645	14855
4081	.7830	.2525	.1265	625	14675
4084	.7870	.2525	.1280	610	14155
4087	.7885	.2500	.1345	660	14721
4089	.7880	.2540	.1365	675	14602
4090	.7870	.2530	.1370	635	13740
4091	.7875	.2525	.1355	605	13262
4092	.7880	.2535	.1355	645	14083
4093	.7890	.2530	.1310	620	14030
4094	.7890	.2535	.1345	640	14078
4095	.7880	.2495	.1405	590	12623
4096	.7890	.2520	.1340	630	13993
4097	.7850	.2530	.1310	640	14483
4098	.7855	.2520	.1340	645	14326
4099	.7910	.2515	.1300	600	13764
4101	.7890	.2540	.1350	645	14108
4102	.7885	.2505	.1365	615	13490
4103	.7875	.2535	.1395	590	12513
4104	.7890	.2540	.1360	620	13461
4105	.7840	.2520	.1350	635	13999
4108	.7870	.2535	.1340	655	14462
4109	.7880	.2540	.1340	655	14433
4110	.7880	.2540	.1345	645	14160
4111	.7890	.2530	.1240	625	14942
4112	.7880	.2525	.1440	680	14026
4113	.7880	.2530	.1360	620	13514

Table XIII. Series 4000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
4115	.7860	.2540	.1340	635	13993
4116	.7880	.2500	.1360	640	14118
4117	.7875	.2530	.1430	630	13060
4118	.7865	.2485	.1360	625	13870
4119	.7870	.2520	.1355	650	14277
4120	.7875	.2515	.1325	650	14629
4121	.7900	.2525	.1335	575	12793
4122	.7880	.2480	.1360	605	13453
4124	.7890	.2515	.1435	680	14131
4125	.7845	.2535	.1410	630	13219
4126	.7875	.2540	.1340	655	14433
4128	.7840	.2530	.1365	615	13356
4129	.7885	.2545	.1350	645	14080
4130	.7875	.2525	.1355	620	13591
4131	.7880	.2525	.1345	630	13913
4132	.7890	.2510	.1290	575	13319
4133	.7875	.2530	.1260	645	15175
4134	.7845	.2530	.1365	630	13682
4135	.7860	.2525	.1340	570	12635
4136	.7895	.2510	.1310	630	14370
4139	.7880	.2520	.1425	645	13471
4140	.7895	.2545	.1250	595	14028

Table XIV. Series 5000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
5001	.6905	.2495	.1140	405	10679
5002	.6870	.2515	.1200	430	10686
5003	.6895	.2515	.1200	520	12922
5004	.6890	.2505	.1205	365	9069
5005	.6880	.2460	.1170	350	9120
5006	.6875	.2510	.1190	415	10421
5007	.6900	.2500	.1200	485	12125
5008	.6875	.2455	.1180	390	10097
5009	.6890	.2505	.1190	410	10316
5010	.6835	.2500	.1185	370	9367
5011	.6890	.2460	.1200	405	10290
5012	.6870	.2445	.1165	390	10269
5013	.6925	.2510	.1195	390	9752
5014	.6890	.2510	.1140	425	11140
5015	.6850	.2505	.1195	490	12277
5016	.6895	.2470	.1240	425	10407
5017	.6885	.2460	.1200	400	10163
5018	.6920	.2500	.1240	420	10161
5019	.6870	.2495	.1220	465	11457
5020	.6875	.2490	.1190	455	11517
5021	.6910	.2515	.1170	420	10705
5022	.6870	.2505	.1195	450	11275
5023	.6910	.2490	.1205	440	10998
5024	.6875	.2490	.1130	375	9996
5025	.6820	.2500	.1180	425	10805
5027	.6890	.2500	.1215	440	10864
5028	.6880	.2500	.1205	425	10581
5029	.6870	.2490	.1165	455	11764
5031	.6925	.2515	.1195	415	10356
5032	.6940	.2505	.1170	350	8956

Table XIV. Series 5000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
5033	.6875	.2505	.1210	465	11506
5034	.6940	.2525	.1180	420	10572
5035	.6880	.2510	.1200	450	11205
5036	.6910	.2520	.1190	485	12130
5037	.6885	.2505	.1225	450	10998
5038	.6875	.2505	.1185	425	10738
5039	.6875	.2505	.1235	490	11879
5040	.6880	.2490	.1190	405	10251
5041	.6885	.2500	.1140	445	11711
5043	.6915	.2500	.1125	455	12133
5045	.6875	.2505	.1205	435	10808
5046	.6890	.2510	.1195	450	11252
5047	.6875	.2510	.1180	375	9496
5048	.6890	.2515	.1195	400	9982
5049	.6905	.2510	.1240	450	10844
5050	.6900	.2505	.1210	435	10767
5053	.6875	.2485	.1190	400	10145
5054	.6885	.2505	.1200	505	12600
5055	.6920	.2485	.1195	435	10986
5056	.6870	.2520	.1140	380	9921
5057	.6900	.2500	.1200	465	11625
5058	.6895	.2505	.1140	375	9849
5059	.6875	.2500	.1230	430	10488
5060	.6880	.2495	.1195	460	11571
5061	.6895	.2510	.1205	400	9919
5062	.6885	.2510	.1195	470	11752
5063	.6890	.2500	.1135	395	10441
5064	.6890	.2505	.1210	435	10764
5067	.6905	.2515	.1175	400	10152
5068	.6900	.2485	.1190	485	12301

Table XIV. Series 5000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
5069	.6880	.2510	.1205	470	11655
5070	.6890	.2465	.1170	385	10012
5071	.6835	.2455	.1180	385	9968
5072	.6880	.2505	.1195	500	12527
5074	.6885	.2510	.1190	425	10672
5075	.6895	.2505	.1205	445	11057
5076	.6900	.2505	.1210	465	11506
5077	.6900	.2500	.1205	410	10207
5078	.6745	.2500	.1210	400	9917
5081	.6875	.2495	.1180	440	11209
5083	.6930	.2495	.1180	435	11081
5085	.6910	.2505	.1170	385	9852
5086	.6875	.2525	.1180	405	10195
5087	.6895	.2505	.1205	460	11429
5088	.6960	.2495	.1175	425	10873
5089	.6860	.2505	.1220	480	11780
5090	.6875	.2510	.1210	440	10866
5091	.6890	.2520	.1240	470	11281
5093	.6895	.2500	.1185	410	10380
5094	.6890	.2505	.1210	465	11506
5095	.6900	.2510	.1200	475	11828
5097	.6940	.2520	.1220	425	10368
5099	.6915	.2505	.1195	515	12903
5100	.6905	.2490	.1180	410	10466
5101	.6910	.2490	.1205	445	11123
5102	.6890	.2505	.1200	465	11602
5103	.6845	.2500	.1180	435	11059
5104	.6875	.2495	.1180	350	8916
5106	.6900	.2465	.1200	420	10649
5107	.6905	.2535	.1190	425	10566
5108	.6845	.2500	.1225	405	9918

Table XIV. Series 5000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
5109	.6875	.2490	.1210	465	11575
5110	.6875	.2510	.1230	490	11904
5111	.6950	.2500	.1170	420	10769
5112	.6895	.2475	.1190	460	11714
5113	.6900	.2510	.1195	420	10592
5114	.6970	.2495	.1185	435	11035
5115	.6900	.2500	.1130	370	9823
5116	.6890	.2505	.1210	465	11506
5117	.6910	.2500	.1220	405	9959
5118	.6870	.2495	.1170	410	10534
5119	.6915	.2480	.1190	385	9784
5120	.6895	.2530	.1205	395	9717
5121	.6895	.2510	.1140	365	9567
5122	.6880	.2500	.1210	400	9917
5123	.6905	.2500	.1195	455	11423
5124	.6900	.2500	.1195	455	11423
5125	.6880	.2500	.1210	480	11901
5126	.6895	.2515	.1195	475	11854
5127	.6885	.2505	.1195	435	10899
5128	.6880	.2500	.1220	450	11066
5129	.6875	.2510	.1185	405	10212
5130	.6910	.2470	.1185	390	9993
5132	.6910	.2500	.1240	435	10524
5134	.6910	.2505	.1185	425	10738
5135	.6900	.2490	.1210	435	10828
5136	.6905	.2515	.1190	390	9773
5137	.6925	.2510	.1190	425	10672
5138	.6900	.2495	.1185	415	10549
5137	.6905	.2490	.1200	405	10166
5142	.6880	.2495	.1180	475	12100
5143	.6900	.2520	.1200	425	13021

Table XIV. Series 5000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
5145	.6890	.2505	.1205	455	11305
5146	.6900	.2515	.1145	445	11590
5147	.6905	.2500	.1135	420	11101
5148	.6890	.2510	.1140	410	10746
5149	.6875	.2515	.1195	425	10606
5150	.6935	.2505	.1175	465	11849
5151	.6875	.2510	.1225	455	11098
5152	.6870	.2500	.1195	420	10544
5153	.6880	.2500	.1200	470	11750
5155	.6890	.2515	.1135	430	10383
5156	.6895	.2485	.1190	410	10399
5158	.6895	.2510	.1140	415	10878
5159	.6875	.2490	.1200	395	9915
5160	.6875	.2515	.1195	395	9857

Table XV. Series 6000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
6002	.6765	.2490	.1160	410	10646
6003	.6770	.2505	.1155	410	10628
6005	.6775	.2480	.1200	455	11467
6006	.6780	.2505	.1185	420	10612
6007	.6745	.2495	.1165	465	11998
6009	.6735	.2505	.1175	485	12358
6010	.6780	.2565	.1165	365	9161
6011	.6770	.2490	.1160	410	10646
6012	.6725	.2485	.1165	465	12047
6013	.6735	.2470	.1175	420	10854
6014	.6730	.2490	.1185	395	10040
6016	.6720	.2510	.1160	410	10561
6017	.6720	.2485	.1160	405	10537
6019	.6740	.2500	.1205	460	11452
6020	.6710	.2510	.1180	405	10256
6021	.6740	.2485	.1170	495	12769
6023	.6760	.2475	.1200	415	10480
6025	.6740	.2505	.1165	430	11051
6026	.6735	.2540	.1180	395	9884
6027	.6740	.2495	.1155	425	11061
6028	.6785	.2500	.1145	420	11004
6029	.6710	.2510	.1155	400	10348
6030	.6740	.2500	.1175	415	10596
6031	.6720	.2455	.1160	435	11456
6032	.6720	.2510	.1175	435	11062
6033	.6795	.2500	.1175	440	11234
6034	.6725	.2500	.1195	490	12301
6035	.6725	.2480	.1165	420	10903
6036	.6775	.2505	.1160	435	11228
6037	.6720	.2465	.1180	470	12119

Table XV. Series 6000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
6038	.6745	.2460	.1205	385	9741
6040	.6790	.2500	.1195	425	10669
6041	.6785	.2500	.1180	465	11822
6043	.6715	.2495	.1155	375	10280
6046	.6810	.2515	.1175	445	11294
6047	.6760	.2480	.1195	415	10502
6048	.6740	.2545	.1160	410	10416
6049	.6735	.2450	.1185	415	10721
6050	.6740	.2515	.1160	455	11697
6051	.6740	.2510	.1160	465	11978
6052	.6795	.2475	.1160	425	11102
6053	.6760	.2455	.1170	435	11358
6054	.6740	.2485	.1165	345	9715
6055	.6735	.2495	.1170	425	10919
6056	.6740	.2455	.1165	405	10620
6057	.6770	.2480	.1175	385	9909
6058	.6740	.2475	.1175	440	11348
6059	.6735	.2480	.1160	425	11080
6060	.6740	.2495	.1195	400	10062
6061	.6730	.2500	.1170	440	11282
6062	.6735	.2505	.1195	425	10648
6063	.6765	.2495	.1180	430	10954
6064	.6720	.2495	.1105	325	8841
6065	.6730	.2485	.1190	495	12554
6066	.6720	.2480	.1175	420	10810
6067	.6810	.2495	.1160	460	11920
6069	.6735	.2500	.1195	440	11046
6070	.6735	.2490	.1190	400	10125
6071	.6720	.2495	.1175	440	11257
6072	.6755	.2480	.1145	335	10169

Table XV. Series 6000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
6073	.6775	.2505	.1170	395	10108
6074	.6735	.2515	.1205	475	11755
6075	.6725	.2485	.1195	470	11870
6076	.6760	.2505	.1170	425	10876
6077	.6730	.2490	.1145	375	9865
6078	.6725	.2465	.1155	365	9615
6079	.6715	.2470	.1165	440	11468
6080	.6730	.2470	.1200	425	10754
6081	.6725	.2470	.1150	380	10033
6082	.6725	.2515	.1115	355	9537
6083	.6740	.2490	.1205	470	11748
6084	.6800	.2505	.1175	400	10192
6085	.6735	.2440	.1200	410	10502
6086	.6790	.2475	.1170	400	10360
6087	.6770	.2500	.1115	355	9552
6088	.6730	.2500	.1175	410	10468
6089	.6740	.2510	.1205	470	11655
6090	.6740	.2485	.1165	375	9715
6091	.6735	.2485	.1160	430	11188
6092	.6735	.2505	.1160	415	10711
6093	.6740	.2520	.1180	440	11098
6094	.6730	.2485	.1175	415	10660
6095	.6725	.2520	.1150	400	10352
6096	.6735	.2495	.1180	435	11081
6097	.6775	.2465	.1150	395	10451
6098	.6735	.2510	.1195	445	11127
6099	.6715	.2500	.1155	415	10779
6101	.6740	.2480	.1155	435	11390
6104	.6735	.2470	.1170	400	10381
6105	.6755	.2490	.1155	415	10823

Table XV. Series 6000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
6106	.6765	.2500	.1205	435	10830
6107	.6780	.2485	.1155	440	11498
6108	.6745	.2495	.1205	450	11226
6109	.6715	.2490	.1175	490	12561
6110	.6795	.2500	.1170	425	10897
6111	.6735	.2495	.1195	510	12829
6112	.6730	.2490	.1185	465	11819
6114	.6780	.2495	.1155	410	10671
6115	.6815	.2515	.1160	395	10155
6116	.6715	.2495	.1180	410	10445
6118	.6730	.2485	.1175	410	10531
6119	.6730	.2460	.1170	465	12117
6120	.6740	.2485	.1210	410	10227
6121	.6740	.2480	.1150	450	11834
6122	.6785	.2490	.1170	385	9911
6123	.6730	.2510	.1160	485	12493
6124	.6740	.2485	.1170	415	10705
6125	.6775	.2505	.1180	480	12179
6126	.6745	.2545	.1165	430	10877
6127	.6780	.2490	.1170	430	11070
6128	.6730	.2500	.1195	410	10293
6131	.6725	.2500	.1175	455	11617
6133	.6740	.2495	.1100	345	9428
6135	.6730	.2450	.1105	430	11912
6136	.6735	.2485	.1190	450	11413
6137	.6735	.2480	.1165	455	11811
6138	.6740	.2505	.1175	475	12103
6141	.6740	.2480	.1155	440	11521
6142	.6740	.2490	.1185	420	10676
6143	.6735	.2465	.1190	445	11378

Table XV. Series 6000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
6144	.6760	.2500	.1170	475	12179
6145	.6725	.2485	.1190	420	10652
6146	.6795	.2500	.1205	445	11079
6147	.6725	.2465	.1180	420	10830
6148	.6760	.2480	.1170	420	10856
6149	.6725	.2495	.1170	435	11176
6150	.6795	.2485	.1160	365	9497
6153	.6755	.2495	.1205	455	11351
6155	.6720	.2480	.1170	435	11244
6156	.6730	.2490	.1135	350	9288
6157	.6805	.2515	.1185	440	11073
6158	.6725	.2480	.1180	450	11533
6159	.6745	.2490	.1170	450	11585

Table XVI. Series 7000 Data

<u>Specimen Number</u>	<u>Length (in)</u>	<u>Width (in)</u>	<u>Thickness (in)</u>	<u>Failure Load (lbs)</u>	<u>Shear Strength (psi)</u>
7001	.8345	.2545	.1550	585	11122
7002	.8280	.2510	.1670	580	10378
7003	.8245	.2515	.1650	555	10031
7004	.8350	.2510	.1660	560	10726
7007	.8285	.2545	.1685	600	10494
7008	.8350	.2535	.1700	515	8963
7009	.8340	.2495	.1535	535	10477
7012	.8335	.2530	.1580	545	10225
7013	.8345	.2510	.1575	480	9106
7014	.8350	.2520	.1675	525	9328
7016	.8340	.2525	.1560	500	9520
7017	.8350	.2520	.1600	530	9859
7019	.8345	.2535	.1520	530	10316
7020	.8345	.2485	.1640	570	10490
7021	.8340	.2520	.1695	570	10008
7023	.8305	.2535	.1710	550	9516
7024	.8340	.2515	.1635	540	9849
7025	.8245	.2520	.1675	590	10483
7026	.8340	.2500	.1675	580	10388
7029	.8335	.2510	.1700	565	9931
7030	.8340	.2515	.1580	480	9060
7031	.8340	.2520	.1675	580	10306
7032	.8340	.2500	.1700	505	8912
7036	.8330	.2535	.1590	500	9304
7038	.8340	.2500	.1555	520	10032
7040	.8345	.2520	.1610	530	9797
7041	.8330	.2520	.1580	505	9513
7042	.8345	.2520	.1700	530	9279
7043	.8340	.2515	.1655	515	9280
7044	.8345	.2520	.1675	540	9595

Table XVI. Series 7000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
7046	.8340	.2525	.1610	585	10793
7050	.8325	.2540	.1590	525	9750
7051	.8235	.2525	.1670	580	10316
7052	.8245	.2500	.1575	510	9714
7059	.8350	.2520	.1685	545	9626
7060	.8345	.2510	.1665	590	10588
7061	.8330	.2520	.1665	595	10636
7062	.8350	.2505	.1670	580	10398
7063	.8315	.2550	.1700	560	9689
7065	.8320	.2525	.1700	500	8736
7066	.8345	.2495	.1605	560	10488
7068	.8345	.2525	.1650	580	10441
7071	.8295	.2540	.1700	590	10248
7072	.8350	.2465	.1645	565	10450
7073	.8300	.2520	.1690	600	10566
7074	.8330	.2540	.1680	615	10809
7076	.8335	.2535	.1675	540	9538
7077	.8345	.2520	.1685	510	9008
7078	.8330	.2525	.1525	530	10323
7079	.8340	.2505	.1645	595	10829
7080	.8345	.2535	.1595	585	10851
7083	.8270	.2515	.1555	525	10068
7084	.8270	.2525	.1640	540	9780
7086	.8350	.2510	.1655	580	10472
7087	.8345	.2500	.1630	580	10675
7088	.8335	.2540	.1695	580	10104
7090	.8335	.2530	.1675	530	9380
7093	.8345	.2540	.1560	570	10789
7094	.8350	.2540	.1685	510	8937
7095	.8350	.2535	.1670	525	9301

Table XVI. Series 7000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
7096	.8350	.2500	.1655	540	9789
7097	.8340	.2495	.1695	545	9665
7100	.8340	.2515	.1655	585	10541
7104	.8340	.2550	.1635	580	10434
7105	.8335	.2535	.1625	565	10287
7107	.8260	.2510	.1600	540	10085
7111	.8340	.2550	.1690	570	10212
7113	.8335	.2535	.1575	465	9262
7114	.8255	.2515	.1630	580	8735
7116	.8345	.2530	.1590	590	11000
7117	.8345	.2515	.1650	545	9850
7120	.8330	.2525	.1680	620	10962
7121	.8265	.2530	.1585	530	9913
7122	.8340	.2560	.1670	600	10526
7123	.8260	.2525	.1675	520	9221
7125	.8335	.2535	.1675	580	10245

Table XVII. Series 8000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)	Remarks
8001	.8410	.2550	.1710	590	10148	
8005	.8410	.2430	.1750	560	9877	Flaw
8006	.8395	.2505	.1755	560	9554	Flaw
8007	.8400	.2515	.1595	540	10096	
8009	.8410	.2525	.1670	505	8982	
8010	.8405	.2545	.1665	555	9823	
8011	.8340	.2460	.1665	550	10071	
8015	.8395	.2540	.1745	550	9307	
8016	.8375	.2540	.1520	520	10102	
8017	.8355	.2510	.1520	570	11205	Flaw
8023	.8425	.2530	.1750	580	9825	Flaw
8026	.8395	.2570	.1750	550	9172	
8028	.8335	.2515	.1635	580	10579	Flaw
8033	.8405	.2510	.1710	540	9436	
8035	.8405	.2515	.1650	460	8314	Flaw
8037	.8410	.2480	.1720	560	9846	
8038	.8405	.2580	.1700	585	10003	
8040	.8415	.2495	.1745	510	8785	Flaw
8041	.8345	.2465	.1710	575	10231	
8042	.8365	.2500	.1590	470	8868	Flaw
8043	.8415	.2520	.1725	575	9921	Flaw
8044	.8390	.2425	.1735	555	9893	Flaw
8045	.8385	.2495	.1740	590	10193	
8047	.8385	.2500	.1750	560	9600	
8051	.8400	.2490	.1645	570	10437	
8053	.8420	.2520	.1740	535	9151	Flaw
8055	.8415	.2475	.1755	530	9151	Flaw
8056	.8410	.2525	.1745	575	9788	Flaw
8062	.8370	.2500	.1670	545	9790	Flaw
8063	.8380	.2470	.1720	585	10327	

Table XVII. Series 8000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)	Remarks
8064	.8410	.2430	.1740	525	9312	Flaw
8065	.8400	.2525	.1700	570	9959	
8066	.8405	.2530	.1720	555	9565	
8070	.8405	.2435	.1745	550	9708	Flaw
8071	.8380	.2465	.1710	580	10320	Flaw
8072	.8405	.2510	.1655	485	8757	Flaw
8075	.8390	.2530	.1710	550	9535	
8079	.8400	.2515	.1690	580	10234	
8081	.8410	.2535	.1705	565	9804	
8085	.8405	.2515	.1660	520	9342	Flaw
8087	.8380	.2530	.1650	525	9432	
8091	.8375	.2520	.1660	560	10040	
8096	.8415	.2520	.1750	535	9099	Flaw
8097	.8405	.2520	.1590	420	7862	Flaw
8098	.8400	.2515	.1580	470	8871	Flaw
8099	.8400	.2520	.1700	595	10417	Flaw
8100	.8415	.2505	.1695	560	9892	
8101	.8375	.2540	.1590	450	8357	Flaw
8102	.8370	.2515	.1675	530	10326	
8105	.8415	.2475	.1650	550	10101	
8106	.8395	.2540	.1740	545	9249	
8108	.8395	.2525	.1730	555	9529	
8113	.8410	.2515	.1730	570	9825	Flaw
8116	.8405	.2505	.1715	560	9776	Flaw
8120	.8415	.2540	.1750	590	9955	Flaw
8122	.8400	.2520	.1645	570	10313	
8123	.8420	.2520	.1695	545	9569	Flaw
8124	.8165	.2515	.1725	560	9681	Flaw
8126	.8395	.2530	.1525	460	8942	
8129	.8430	.2540	.1690	555	9697	

Table XVIII. Series 9000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)	Remarks
9001	.8305	.2500	.1640	600	10976	Flaw
9002	.8315	.2480	.1610	550	10331	Flaw
9003	.8290	.2475	.1605	505	9535	
9004	.8315	.2480	.1570	570	10980	
9006	.8325	.2445	.1585	540	10451	Flaw
9008	.8315	.2510	.1595	550	10304	
9009	.8295	.2450	.1635	585	10953	Flaw
9011	.8290	.2485	.1610	600	11248	
9012	.8255	.2495	.1610	610	11389	
9016	.8310	.2495	.1605	570	10676	
9017	.8315	.2500	.1615	500	9288	Flaw
9018	.8315	.2450	.1590	570	10974	Flaw
9020	.8315	.2490	.1595	555	10481	
9024	.8275	.2500	.1640	585	10701	
9025	.8240	.2505	.1620	550	10165	Flaw
9026	.8325	.2505	.1600	600	11228	Flaw
9031	.8305	.2475	.1600	595	11269	Flaw
9032	.8275	.2495	.1595	565	8764	
9034	.8270	.2500	.1620	580	10741	
9035	.8310	.2505	.1600	540	10105	Flaw
9037	.8300	.2470	.1610	600	11316	
9039	.8280	.2440	.1630	580	10937	Flaw
9043	.8300	.2500	.1615	570	10588	
9045	.8310	.2510	.1615	545	10084	
9048	.8230	.2510	.1580	550	10401	Flaw
9050	.8300	.2505	.1615	570	10567	Flaw
9053	.8275	.2505	.1565	583	11192	
9057	.8330	.2475	.1585	570	10898	
9058	.8295	.2460	.1625	605	11351	
9060	.8275	.2490	.1645	565	10345	Flaw

Table XVIII. Series 9000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)	Remarks
9063	.8310	.2500	.1605	550	10280	
9064	.8325	.2495	.1615	540	10051	Flaw
9065	.8310	.2490	.1610	530	9915	
9066	.8305	.2495	.1630	590	10881	Flaw
9070	.8310	.2490	.1600	575	10825	
9071	.8280	.2490	.1605	550	10322	
9072	.8285	.2495	.1620	585	10855	Flaw
9073	.8315	.2480	.1590	550	10461	
9074	.8290	.2495	.1550	550	10660	
9077	.8305	.2490	.1590	550	10419	
9078	.8310	.2440	.1600	580	11142	
9081	.8315	.2505	.1590	580	10922	
9082	.8285	.2485	.1600	580	10941	
9083	.8325	.2510	.1595	570	10678	Flaw
9084	.8290	.2490	.1610	585	10944	
9085	.8315	.2515	.1625	550	10093	Flaw
9087	.8305	.2500	.1620	600	11111	
9088	.8300	.2490	.1615	550	10258	
9092	.8310	.2480	.1595	555	10523	
9094	.8315	.2490	.1615	540	10071	
9096	.8250	.2475	.1615	530	9945	Flaw
9098	.8270	.2505	.1620	530	9795	Flaw
9099	.8295	.2495	.1615	610	11354	
9102	.8335	.2510	.1550	560	10796	
9104	.8315	.2475	.1610	570	10728	
9105	.8295	.2500	.1620	580	10741	Flaw

Table XIX. Series 10000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
10001	.814	.248	.163	590	10946
10002	.817	.251	.160	545	10178
10003	.817	.248	.159	580	11032
10004	.815	.249	.162	555	10319
10005	.816	.240	.151	600	12417
10006	.816	.250	.161	565	10528
10007	.817	.250	.159	580	10943
10008	.816	.241	.158	565	11128
10009	.814	.249	.163	600	11087
10010	.815	.235	.156	550	11252
10011	.813	.247	.164	590	10924
10012	.312	.249	.156	510	9847
10013	.818	.245	.164	590	11013
10014	.815	.248	.164	580	10695
10015	.813	.250	.155	590	11419
10016	.815	.250	.161	585	10901
10017	.816	.249	.160	530	9977
10019	.814	.250	.160	585	10969
10020	.816	.245	.158	550	10656
10021	.816	.249	.161	575	10757
10022	.814	.247	.156	565	10997
10023	.817	.250	.162	600	11111
10024	.816	.243	.152	570	11574
10025	.815	.250	.155	575	11129
10026	.815	.244	.154	530	10579
10027	.816	.249	.159	565	10703
10029	.818	.250	.157	570	10892
10030	.814	.253	.152	610	11897
10031	.813	.247	.163	570	10618
10033	.816	.245	.157	575	11211

Table XIX. Series 10000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
10035	.816	.249	.158	510	9722
10036	.813	.248	.156	570	11050
10037	.819	.251	.160	605	11299
10038	.816	.250	.164	600	10976
10039	.819	.245	.161	600	11408
10040	.816	.249	.164	550	10101
10041	.816	.247	.163	590	10991
10042	.815	.249	.161	585	10944
10043	.816	.249	.162	580	10784
10044	.815	.249	.157	590	11319
10045	.815	.245	.160	580	11097
10046	.818	.247	.159	600	11458
10047	.816	.249	.162	565	10505
10048	.814	.248	.156	575	11147
10049	.815	.250	.154	600	11688
10050	.815	.248	.162	535	9987
10051	.816	.248	.153	590	11662
10052	.816	.246	.161	535	10131
10053	.815	.251	.163	560	10266
10054	.814	.247	.164	600	11109
10055	.819	.250	.160	535	10031
10056	.814	.245	.161	570	10838
10057	.816	.247	.159	595	11363
10058	.814	.248	.158	590	11293
10059	.817	.249	.158	575	10962
10060	.814	.250	.160	545	10219
10061	.814	.249	.159	565	10703
10062	.815	.251	.164	575	10476
10063	.818	.248	.163	590	10946
10064	.813	.250	.157	545	10414

Table XIX. Series 10000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
10065	.813	.249	.157	540	10360
10066	.815	.251	.161	610	11321
10067	.814	.250	.161	570	10621
10068	.813	.251	.156	580	11109
10069	.816	.251	.156	510	9769
10070	.816	.249	.162	530	10784
10071	.816	.251	.158	570	11158
10072	.815	.245	.162	600	11338
10073	.813	.249	.161	605	11319
10074	.814	.248	.160	580	10963
10075	.813	.246	.161	585	11078
10076	.815	.247	.162	590	11059
10077	.816	.248	.161	595	11176
10078	.818	.251	.160	550	10271
10079	.816	.248	.157	555	10691
10080	.815	.248	.163	570	10575
10081	.815	.248	.158	585	11197
10082	.814	.248	.159	560	10651
10083	.815	.250	.160	595	11156
10084	.815	.245	.126	600	11338
10085	.815	.251	.162	600	11067
10086	.815	.248	.156	605	11728
10087	.814	.247	.162	600	11246
10088	.819	.251	.161	600	11136
10089	.814	.248	.164	585	10788
10090	.815	.250	.158	565	10728
10091	.815	.249	.164	600	11020
10092	.814	.251	.159	570	10712
10093	.816	.251	.162	540	9960
10094	.815	.249	.158	580	11057

Table XIX. Series 10000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
10095	.815	.249	.160	555	10448
10096	.816	.251	.162	595	10975
10097	.814	.248	.169	565	10419
10098	.815	.247	.161	620	11693
10099	.814	.250	.164	600	10976
10100	.816	.247	.158	590	11339

Table XX. Series 11000 Data

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
11001	.7920	.2565	.1535	690	13144
11002	.7870	.2560	.1515	685	13246
11003	.7850	.2530	.1545	730	14007
11004	.7850	.2505	.1540	700	13609
11005	.7880	.2520	.1540	635	12272
11006	.7875	.2495	.1525	650	12813
11007	.7925	.2510	.1535	655	12750
11008	.7880	.2510	.1535	690	13432
11009	.7855	.2520	.1530	715	13908
11010	.7845	.2490	.1535	675	13245
11011	.7870	.2525	.1525	680	13245
11012	.7880	.2530	.1525	690	13413
11013	.7905	.2530	.1560	730	13872
11014	.7850	.2545	.1530	680	13098
11015	.7770	.2560	.1530	740	14170
11016	.7845	.2510	.1520	680	13368
11017	.7860	.2490	.1540	605	13789
11018	.7860	.2545	.1555	710	13456
11019	.7860	.2510	.1545	710	13731
11020	.7870	.2515	.1520	675	13243
11021	.7850	.2500	.1535	700	13681
11022	.7850	.2525	.1530	645	12522
11023	.7875	.2505	.1525	600	11780
11025	.7785	.2560	.1545	700	13274
11026	.7860	.2560	.1555	760	14319
11027	.7845	.2520	.1540	630	12175
11028	.7855	.2520	.1550	805	15457
11029	.7860	.2520	.1525	690	13466
11030	.7860	.2550	.1545	710	13516
11031	.7730	.2560	.1530	620	11872

Table XX. Series 11000 Data (cont'd.)

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
11032	.7880	.2545	.1530	680	13098
11033	.7865	.2505	.1525	685	13449
11036	.7860	.2510	.1530	680	13280
11038	.7725	.2485	.1530	675	13315
11040	.7860	.2510	.1540	740	14358
11041	.7860	.2530	.1530	715	13853
11042	.7875	.2510	.1530	760	13085
11043	.7845	.2495	.1525	705	13897
11044	.7870	.2515	.1535	680	13211
11045	.7860	.2510	.1535	690	13432
11046	.7875	.2545	.1540	630	12056
11047	.6860	.2525	.1535	660	12771
11048	.7850	.2520	.1540	690	13335
11049	.7865	.2560	.1550	675	12758
11050	.7890	.2540	.1530	710	13702
11051	.7875	.2495	.1535	715	14002
11052	.7880	.2510	.1540	675	13485
11054	.7870	.2530	.1530	675	13078
11055	.7790	.2465	.1515	670	13456
11057	.7845	.2570	.1545	730	13789
11059	.7870	.2530	.1530	645	13078
11060	.7760	.2550	.1540	725	13846
11061	.7840	.2515	.1525	685	13395
11062	.7865	.2520	.1560	680	12973
11063	.7840	.2510	.1525	690	13520
11064	.7870	.2540	.1545	700	13378
11065	.7860	.2450	.1540	685	13616
11066	.7845	.2525	.1520	660	12897
11067	.7855	.2520	.1520	625	12238
11069	.7850	.2515	.1540	670	12974

Table XX. Series 11000 Data (cont'd.).

Specimen Number	Length (in)	Width (in)	Thickness (in)	Failure Load (lbs)	Shear Strength (psi)
11070	.7865	.2550	.1505	675	13191
11071	.7870	.2510	.1525	695	13618
11072	.7855	.2500	.1540	660	12857
11076	.7740	.2555	.1560	700	13172
11077	.7855	.2565	.1545	675	12775
11078	.7870	.2490	.1530	640	12599
11079	.7855	.2540	.1535	735	14139
11080	.7875	.2565	.1550	700	13205
11081	.7865	.2550	.1540	715	13655
11082	.7860	.2540	.1530	700	13509
11083	.7820	.2550	.1535	690	13221
11084	.7750	.2520	.1520	690	13510
11085	.7875	.2520	.1525	670	13076
11086	.7860	.2525	.1535	725	14029
11087	.7860	.2520	.1550	690	13249
11088	.7800	.2490	.1530	700	13781
11089	.7850	.2510	.1535	720	14016
11090	.7855	.2520	.1540	680	13142
11091	.7840	.2520	.1525	655	12783
11092	.7865	.2555	.1505	680	13263
11093	.7850	.2535	.1540	745	14313
11094	.7805	.2500	.1525	700	13770
11095	.7860	.2560	.1550	710	13420
11096	.7840	.2500	.1530	695	13627
11097	.7860	.2550	.1545	700	13326
11098	.7790	.2520	.1525	700	13661
11099	.7750	.2565	.1550	680	12828
11102	.7865	.2555	.1540	710	13533
11103	.7855	.2520	.1540	680	13142
11104	.7870	.2510	.1555	680	13067

Table XX. Series 11000 Data (cont'd.)

<u>Specimen Number</u>	<u>Length (in)</u>	<u>Width (in)</u>	<u>Thickness (in)</u>	<u>Failure Load (lbs)</u>	<u>Shear Strength (psi)</u>
11105	.7850	.2555	.1520	685	13229
11106	.7845	.2500	.1540	690	13442
11107	.7860	.2515	.1540	640	12393
11108	.7860	.2565	.1550	750	14148
11109	.7840	.2520	.1525	710	13856
11110	.7860	.2530	.1535	690	13325
11112	.7870	.2550	.1510	680	13245
11113	.7770	.2520	.1525	700	13661
11114	.7865	.2530	.1500	700	13843

Table XXI. Statistical Data

Series	Manufacturer (Task)	Specimen Quantity	Minimum Value	Mean	Normal Distribution Standard Deviation	Weibull Scale Factor	Weibull Distribution Shape Factor
1000	UC (III)	100	10676	14140	776	14500	21.245
2000	Narmco (III)	55	9290	10572	407	10759	30.782
3000	Hercules (III)	85	8719	12612	1248	13195	11.205
4000	UC (III)	112	12513	13867	617	14145	27.295
5000	Hercules (III)	136	8916	10825	840	11193	15.647
6000	Hercules (III)	131	8841	10940	796	11288	16.792
7000	Narmco (IV)	76	8735	10018	601	10287	19.990
8000	Narmco (III)	61	7862	9656	600	9924	19.225
9000	Narmco (IV)	57	8764	10600	538	10944	23.349
10000	Narmco (IV)	96	9722	10294	489	11114	27.016
11000	UC (III)	100	11780	13352	559	13605	28.864

Table XXII. Series 7000 Random Sampling Data

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level	
			Weibull	Normal
76	19.990	10287	7250	8100
45	18.663	10226	7050	7950
44	18.239	10267	7000	7950
44	19.703	10334	7250	8150
44	18.829	10238	7050	8000
43	20.410	10246	7300	8150
41	20.510	10292	7300	8200
41	19.915	10162	7150	8050
40	20.410	10343	7350	8250
40	21.445	10304	7450	8250
40	19.582	10245	7150	8050
40	19.168	10313	7150	8050
38	19.458	10209	7150	8050
37	18.708	10442	7200	8100
37	18.546	10235	7050	7950
36	17.781	10239	6900	7850
36	19.021	10369	7200	8100
36	20.449	10261	7300	8150
35	20.188	10274	7250	8150
35	17.993	10254	6950	7900
35	20.168	10228	7250	8150
34	18.967	10376	7200	8100
33	21.256	10378	7450	8350
30	20.869	10450	7500	8350
29	21.038	10256	7350	8250
28	18.861	10144	7000	7950
21	16.624	10281	6750	7800
18	18.194	10320	7050	8050
18	14.503	10281	6350	7500
17	19.771	10223	7200	8150
17	18.106	10397	7050	8150

Table XXII. Series 7000 Random Sampling Data (cont'd.)

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level Weibull	0.1% Failure Level Normal
17	22.219	10306	7550	8450
17	15.370	10393	6600	7800
17	15.452	10454	6650	7850
17	17.312	10312	6900	7950
17	16.560	10188	6700	7750
16	20.041	10403	7350	8350
16	17.348	10387	6950	8000
16	22.158	10389	7600	8550
15	20.921	10220	7300	8300
15	18.115	10164	6900	7950
14	17.374	10412	6950	8100
12	25.931	10355	7900	8800
12	26.189	10241	7850	8700
12	18.209	10489	7150	8300
12	24.945	10175	7700	8550
11	18.613	10380	7150	8200
11	13.032	10178	6650	7250
11	16.183	10343	6700	7900
11	14.587	10121	6300	7500
11	24.432	10431	7850	8800
11	20.378	10295	7300	8300
10	21.187	10297	7400	8400
10	17.886	10391	7050	8150
10	11.813	10517	6700	7350
9	12.499	10612	6100	7650
9	15.710	10208	6550	7750
8	15.120	10241	6450	7800
8	15.038	10493	6600	7900
8	12.782	10119	5500	7150
7	24.653	10739	7700	8650
7	16.961	10658	7050	8350

Table XXII. Series 7000 Random Sampling Data (cont'd.)

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level	
			Weibull	Normal
7	16.581	10433	6850	8100
6	18.084	10022	6800	7950
6	13.061	10029	6300	7300
6	13.459	10159	6100	7500
6	20.577	10435	7450	8650
6	15.521	10457	6700	8100
6	26.527	10125	7800	8700
6	18.158	10521	7150	8400
5	31.401	9599	7700	8450
5	24.869	9627	7250	8200
5	12.615	9974	7800	7250

Table XXIII. Series 9000 Random Sampling Data

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level Weibull	0.1% Failure Level Normal
57	23.349	10944	8050	8900
37	22.219	10930	8000	8900
37	25.466	10819	8200	9000
34	23.268	10822	8000	8850
32	21.641	10889	7900	8850
31	20.352	10736	7600	8550
31	22.229	10897	7950	8950
31	28.024	10869	8450	9250
30	21.378	10730	7750	8650
30	23.539	10847	8050	8900
30	22.542	10831	7950	8900
30	24.208	10796	8100	8900
30	24.953	10859	8200	9050
28	22.236	10816	7900	8900
28	18.602	10811	7450	8450
27	21.257	10692	7700	8650
27	25.405	10847	8250	9050
27	21.054	10827	7750	8750
27	26.203	10853	8300	9100
27	21.282	10917	7850	8900
26	27.002	10891	8400	9200
25	29.805	10871	8600	9350
24	20.376	11010	7800	8950
24	24.656	10733	8100	8950
24	28.407	10959	8550	9350
23	20.469	10974	7800	8950
17	17.990	10780	7300	8450
17	17.149	10757	7150	8300
15	34.003	10859	8850	9550
14	28.581	10875	8500	9350
14	17.840	10580	7150	8300

Table XXIII. Series 9000 Random Sampling Data (cont'd.)

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level Weibull	Normal
14	15.652	10954	7000	8350
14	34.090	10771	8750	9550
13	17.360	10698	7150	8400
13	30.153	10828	8600	9400
13	24.449	10977	8250	9200
13	16.703	10624	7000	8150
13	21.560	10919	7900	8900
12	25.514	10836	8250	9150
11	25.987	10749	8200	9150
11	22.900	10914	8050	9050
11	22.214	10984	8000	9050
10	22.999	11056	8150	9200
10	21.452	10748	7750	8800
10	18.723	10614	7300	8450
10	36.118	10673	8800	9500
9	19.239	10669	7450	8550
9	14.687	10731	6700	8150
9	15.142	10637	6700	8150
9	14.485	10759	6650	8100
8	46.532	10587	9100	9700
8	18.976	11041	7650	8850
8	40.093	10914	9150	9900
8	34.200	10960	8950	9750
8	16.775	10836	7150	8400
8	27.785	11001	8550	9450
7	34.421	10695	8750	9500
7	31.314	10769	8600	9450
7	33.405	10965	8900	9700
7	21.367	10544	7600	8650
7	24.418	10637	8000	9050
7	21.417	10851	7850	8950

Table XXIII. Series 9000 Random Sampling Data (cont'd.)

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level	
			Weibull	Normal
6	23.217	10981	8150	9250
6	32.157	10517	8450	9300
6	14.920	10824	6800	8200
6	24.974	10999	8550	9550
6	32.979	10983	8900	9700
5	31.850	10460	8400	9250
5	19.854	10699	7550	8700
5	18.926	10664	7400	8850

Table XXIV. Series 10000 Random Sampling Data

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level	
			Weibull	Normal
96	27.016	11114	8600	9300
56	23.581	11154	8300	9150
54	25.923	11128	8500	9300
53	27.489	11127	8650	9400
53	29.216	11079	8700	9450
52	25.272	11062	8900	9200
51	27.668	11099	8600	9400
51	26.949	11081	8550	9350
50	25.213	11103	8400	9250
49	28.975	11084	8700	9450
49	31.802	11080	8900	9550
49	28.641	11136	8700	9500
47	28.329	11139	8700	9450
47	30.067	11133	8800	9550
46	27.745	11108	8650	9400
46	26.700	11079	8550	9300
45	26.361	11186	8600	9400
45	25.731	11134	8500	9300
44	26.215	11138	8550	9350
44	26.028	11089	8500	9250
43	29.135	11088	8700	9450
43	24.527	11222	8450	9300
42	26.450	11088	8500	9300
42	25.681	11198	8550	9350
40	24.538	11214	8450	9300
38	29.078	11070	8700	9450
28	23.034	10988	8100	9050
27	26.755	11080	8550	9350
26	19.512	11145	7800	8800
25	24.848	11095	8400	9250
25	24.691	11104	8350	9250

Table XXIV. Series 10000 Random Sampling Data (cont'd.)

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level Weibull	0.1% Failure Level Normal
24	23.354	11234	8350	9300
24	25.904	11133	8500	9400
21	20.367	11151	7900	8950
21	27.852	11086	8650	9450
20	25.038	11183	8450	9450
19	30.933	11106	8850	9650
19	46.099	11167	9600	10150
19	21.054	11228	8050	9050
19	21.388	11216	8100	9150
18	27.417	11309	8750	9750
18	22.196	11284	8250	9250
18	29.134	11087	8700	9550
18	18.922	11227	7750	8850
17	24.951	11433	8650	9600
17	30.234	11052	8750	9550
16	30.713	11106	8850	9650
16	27.890	11145	8700	9500
16	16.758	11309	7450	8650
15	26.792	11025	8500	9400
15	29.164	11044	8700	9500
14	21.427	11029	7950	8950
14	23.249	10921	8100	9050
13	23.806	11163	8350	9300
13	39.025	11012	9200	9850
13	24.097	11048	8250	9250
13	21.099	11262	8100	9350
12	31.233	11067	8850	9700
12	33.639	11247	9150	9950
12	23.692	11022	8200	9200
12	23.585	11404	8500	9650
12	18.264	11097	7600	8750

Table XXIV. Series 10000 Random Sampling Data (cont'd.).

Sample Size	Shape Factor	Scale Factor	0.1% Failure Level	
			Weibull	Normal
12	22.250	11334	8300	9500
12	18.727	11088	7650	8800
18	25.127	11044	8350	9350
9	21.540	11161	8050	9250
9	21.697	11080	8050	9150
9	20.381	11139	7900	9050
8	31.709	11385	9150	10000
8	19.493	10967	7650	8900
8	23.284	11170	8300	9400
7	17.365	11342	7600	9100
7	18.395	11125	7600	8950
6	21.029	11259	8100	9550
5	20.130	11045	7800	9150
5	26.377	11137	8550	9700

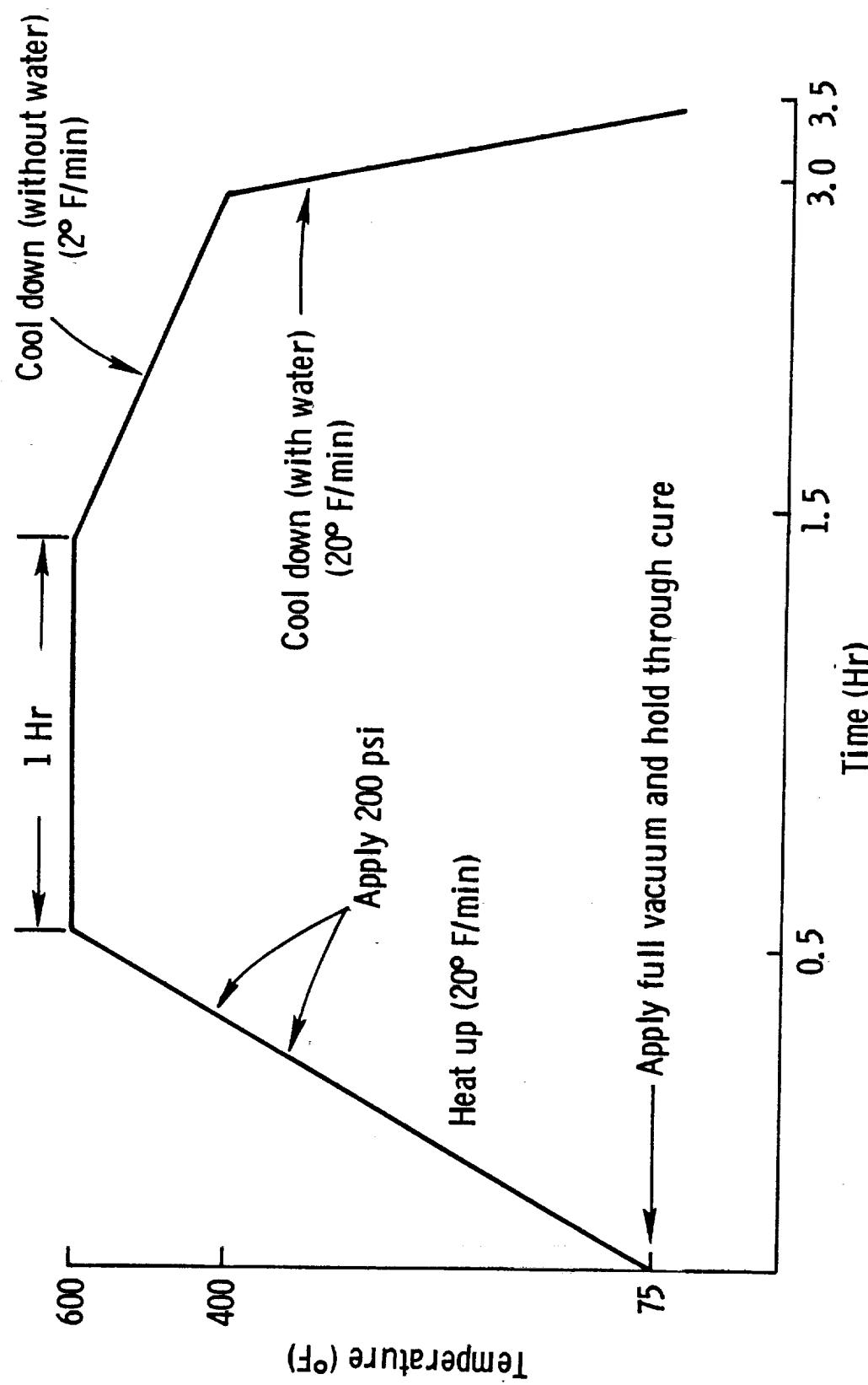


Figure 1. Graphite/Poly sulfone Cure Cycle

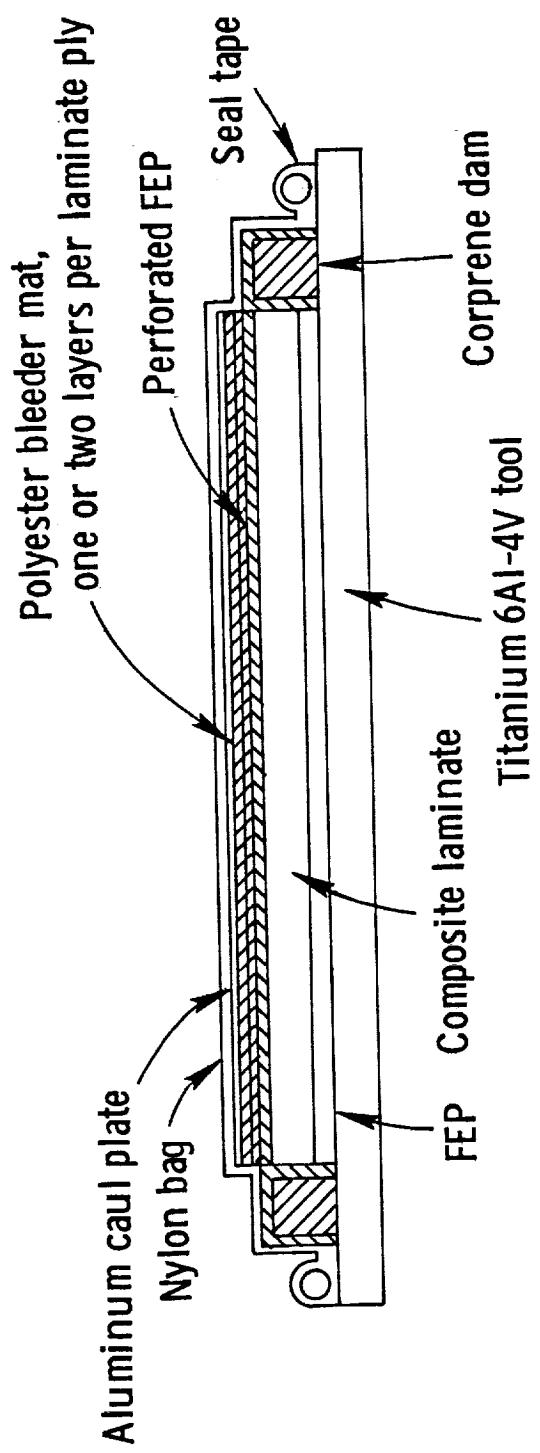


Figure 2. Laminate Layup

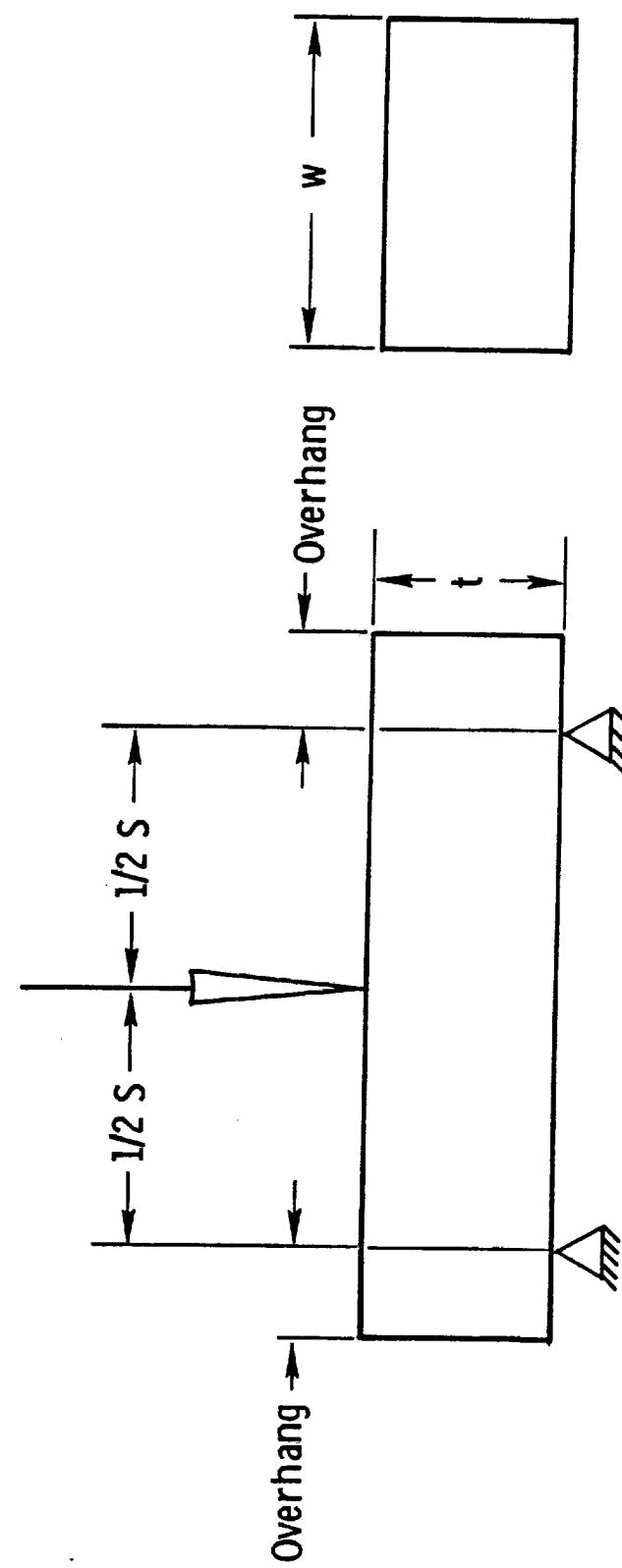


Figure 3. Specimen Dimension Nomenclature

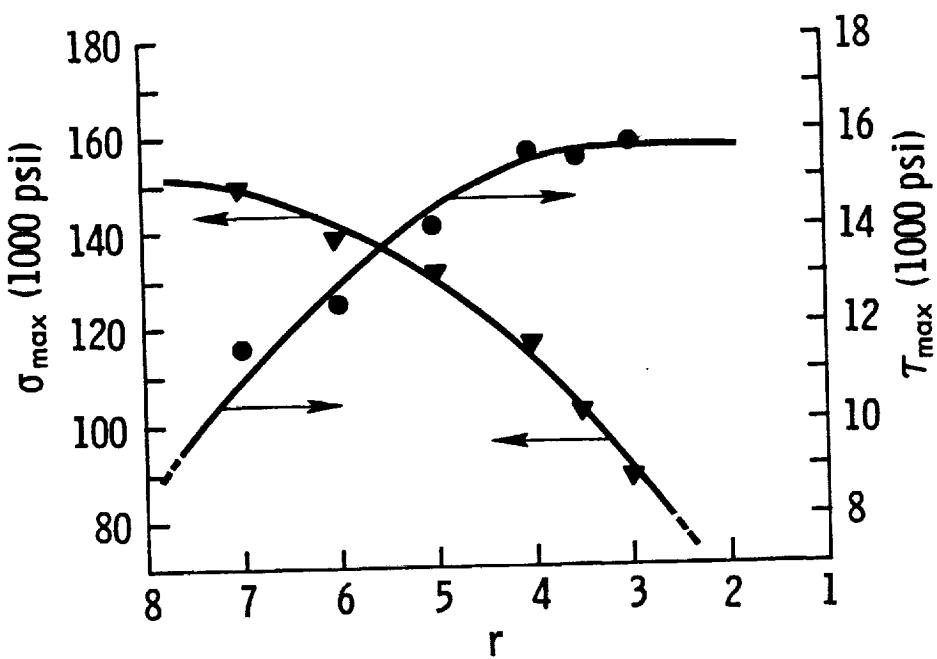


Figure 4. Tensile-Shear Strength Comparison at Various Span-to-Depth Ratios

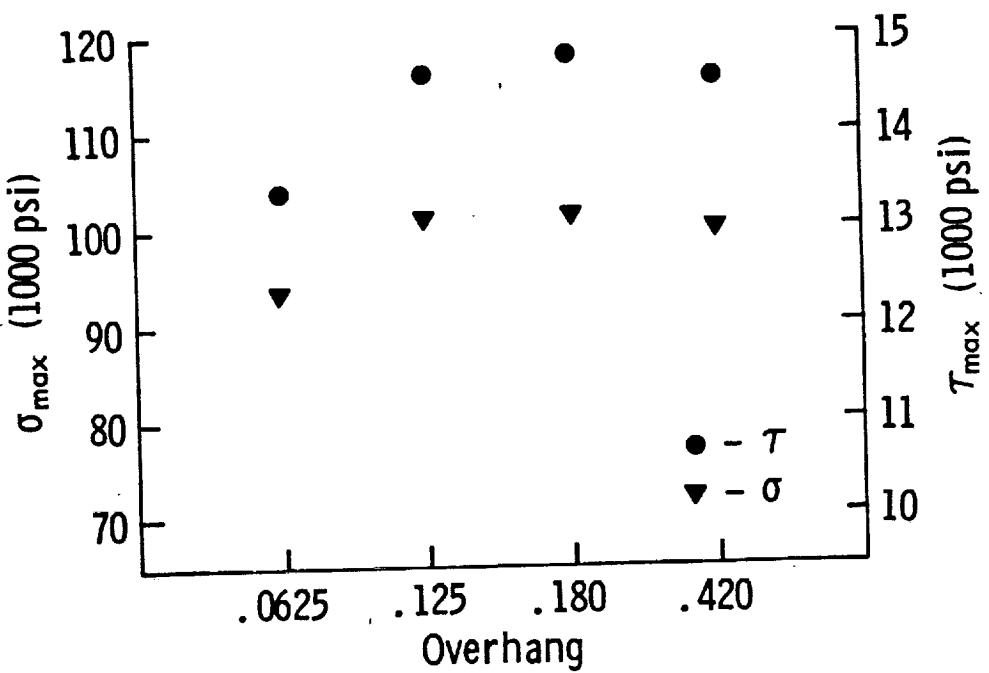
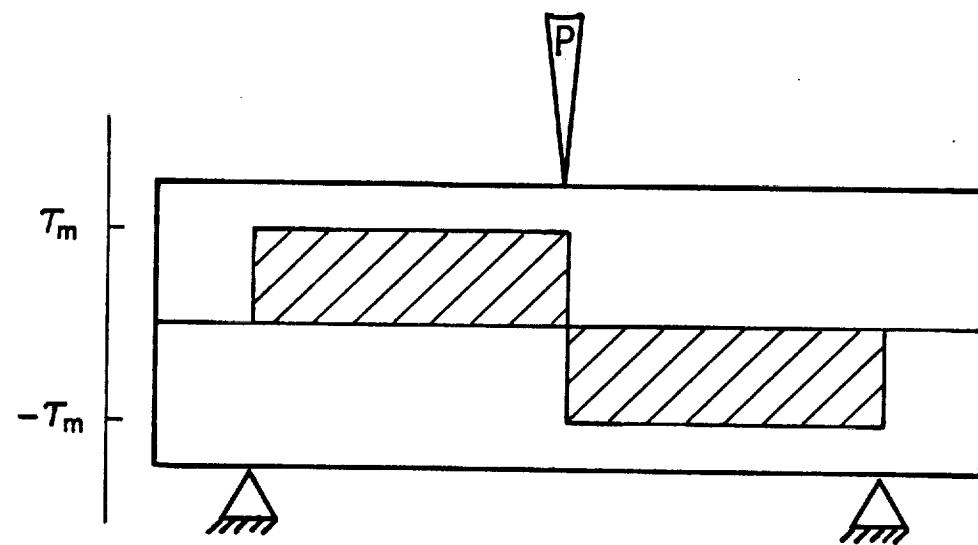
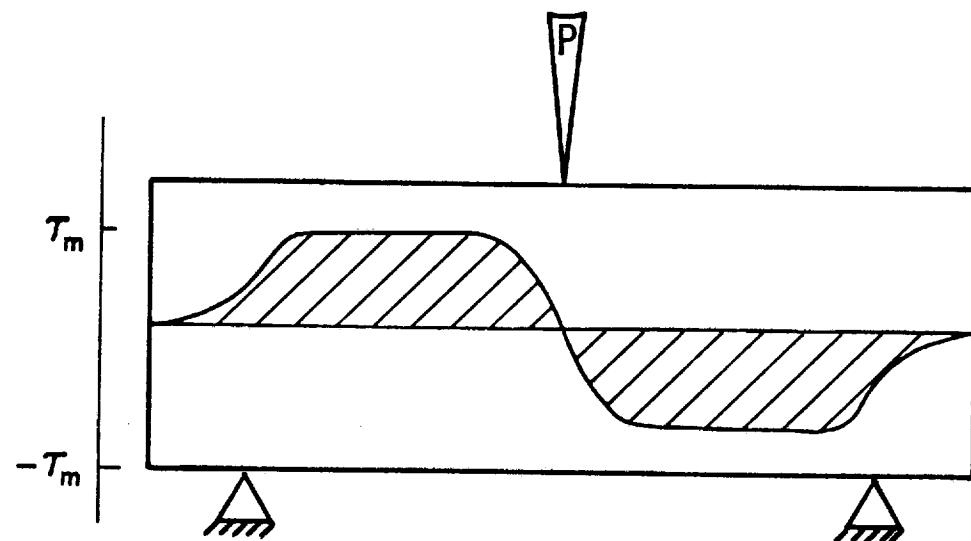


Figure 5. Correlation Between Stress and Overhang



(a) Theoretical Shear Stress Distribution



(b) Physical Shear Stress Distribution

Figure 6. Theoretical and Physical Shear Stress Distribution

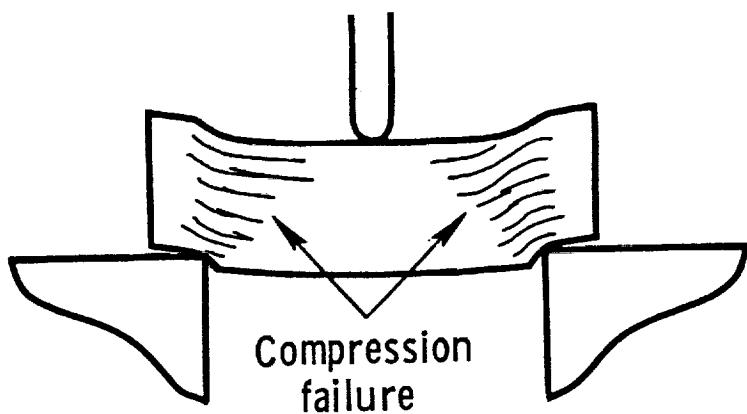


Figure 7. Failure Mode at Span-to-Depth Ratio 2:1

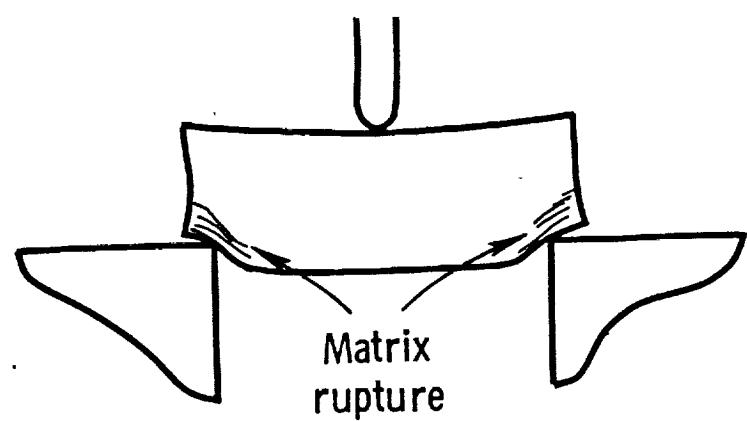


Figure 8. Failure Mode at Overhang of 0.0625"

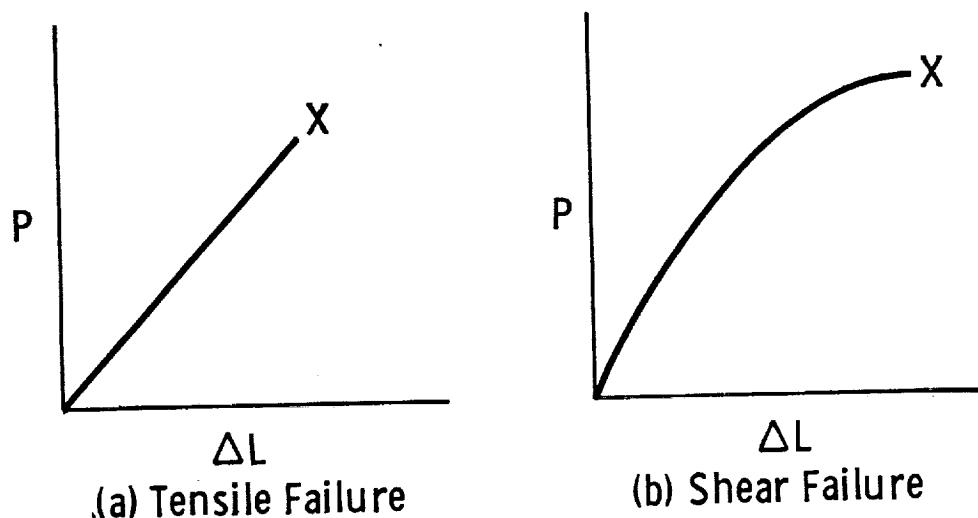


Figure 9. Loading Rate vs. Displacement Rate Comparison

APPENDIX A  
DETERMINATION OF CRITICAL SPAN

Refer to Figure 5 for the short-beam shear specimen nomenclatures.

From elementary beam theory

$$\sigma_{\text{bending}} = \frac{My}{I} = \frac{3Psy}{wt^3}$$

and

$$\tau = \frac{3P}{4wt} \left[ 1 - \left( \frac{2y}{t} \right)^2 \right]$$

mid-way between the bottom supports.  $\sigma$  has its maximum tensile value at the lower fibers ( $y = 0.5t$ ), and

$$\sigma_m = \frac{3Ps}{2wt^2}$$

$\tau$  has its maximum value along the neutral axis, and

$$\tau_m = \frac{3P}{4wt}$$

Taking the ratio of  $\sigma_m$  to  $\tau_m$

$$\frac{\sigma_m}{\tau_m} = \frac{\frac{3Ps}{2wt^2}}{\frac{3P}{4wt}}$$

or

$$\frac{\sigma_m}{\tau} = \frac{2s}{t}$$

If

$$r = \frac{s}{t}$$

then

$$r = \frac{\sigma_m}{2\tau_m}$$

For the beam to fail in shear the following conditions must hold

$$r = \frac{\sigma_m}{2\tau_u}$$

and

$$\sigma_m < \sigma_u$$

where  $\tau_u$  and  $\sigma_u$  are the ultimate strength in shear and tension respectively.

Combining the two conditions,

$$r < \frac{\sigma_u}{2\tau_u} .$$

For example, if it is known that the approximate value for the ultimate shear strength of a material is 8000 psi and the ultimate tensile strength is 80000 psi, then

$$r < \frac{80000}{2(8000)} = 5 .$$

So to insure shear failure the span must be less than five times the thickness.

APPENDIX B  
NASA LAMINATE DESCRIPTION

Series 1000: UNION CARBIDE MACC \$#028849\$P/N795003-1  
PANEL 12" x 3" x 25 PLY LOT#261931 TASK III

Series 2000: NARMCO MACC \$#028913\$P/N795003-2  
PANEL 12" x 3" x 25 PLY LOT#BATCH 19, ROLL 2 TASK III

Series 3000: HERCULES MACC \$#028914\$P/N795003-3  
PANEL 12" x 3" x 25 PLY LOT#RUN425, SPOOL3 TASK III  
(BAG BROKE)

Series 4000: UNION CARBIDE MACC \$#0288493\$P/N795003-1  
PANEL 12" x 3" x 25 PLY LOT#261931 TASK III

Series 5000: HERCULES MACC \$#028914\$P/N795003-3  
PANEL 12" x 3" x 25 PLY LOT#RUN425, SPOOL3 TASK III

Series 6000: HERCULES MACC \$#028914\$P/N795003-3  
PANEL 12" x 3" x 25 PLY LOT#RUN425, SPOOL3 TASK III

Series 7000: NARMCO MACC \$#006794x\$P/N795003-2  
PANEL 12" x 3" x 25 PLY LOT#TE2 TEST,  
BATCH19, ROLL13 TASK IV STEP III

Series 8000: NARMCO MACC \$#028913\$P/N795003-2  
PANEL 12" x 3" x 25 PLY LOT#BATCH19, ROLL2 TASK III

Series 9000: NARMCO MACC \$#006794x\$P/N795003-2  
PANEL 12" x 3" x 25 PLY LOT#TE2 TEST,  
BATCH19, ROLL5 TASK IV STEP I

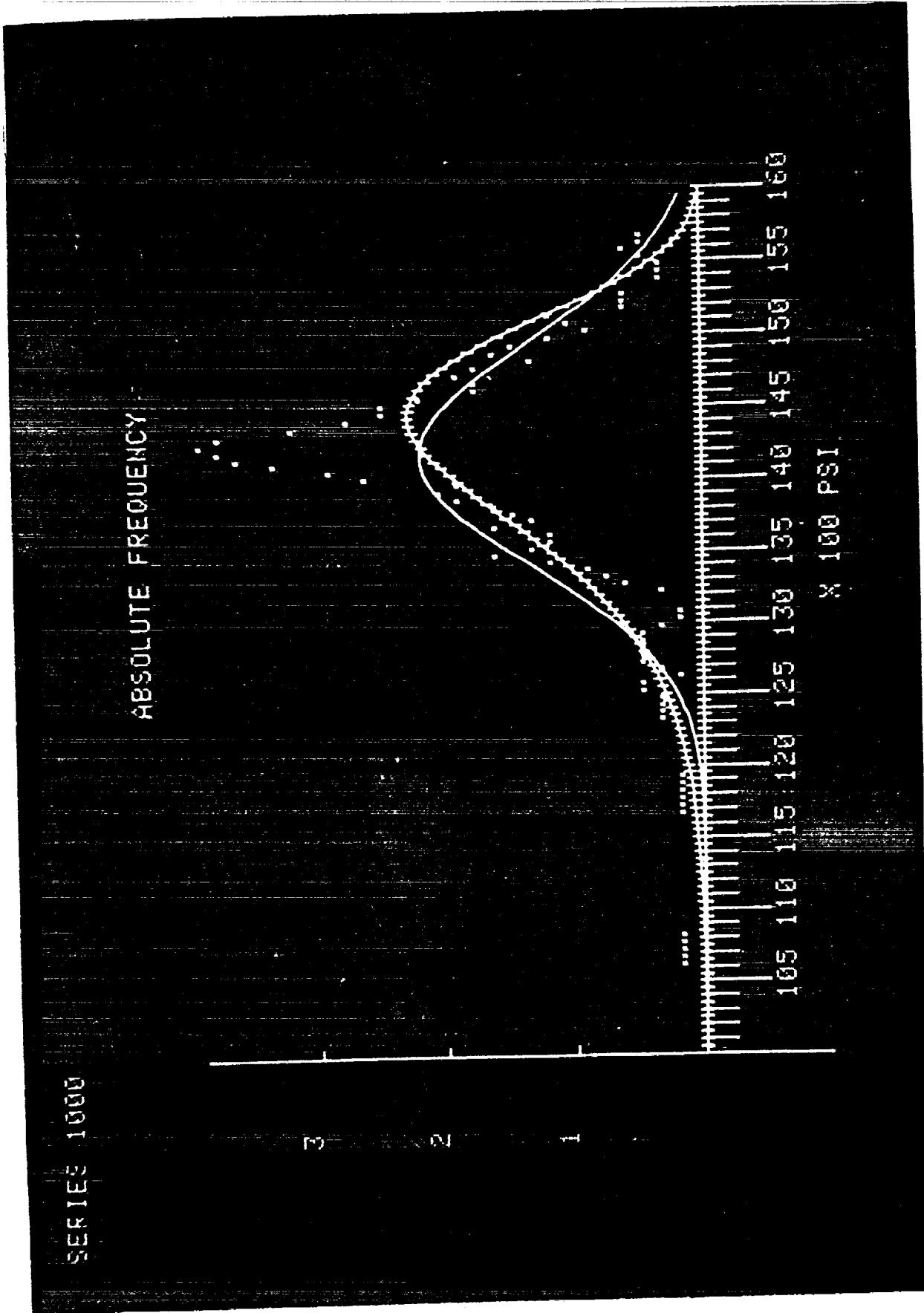
Series 10000: NARMCO MACC \$#006794x\$P/N795003-2  
PANEL 12" x 3" x 25 PLY LOT#TE2 TEST  
BATCH19, ROLL7&8 TASK IV STEP II

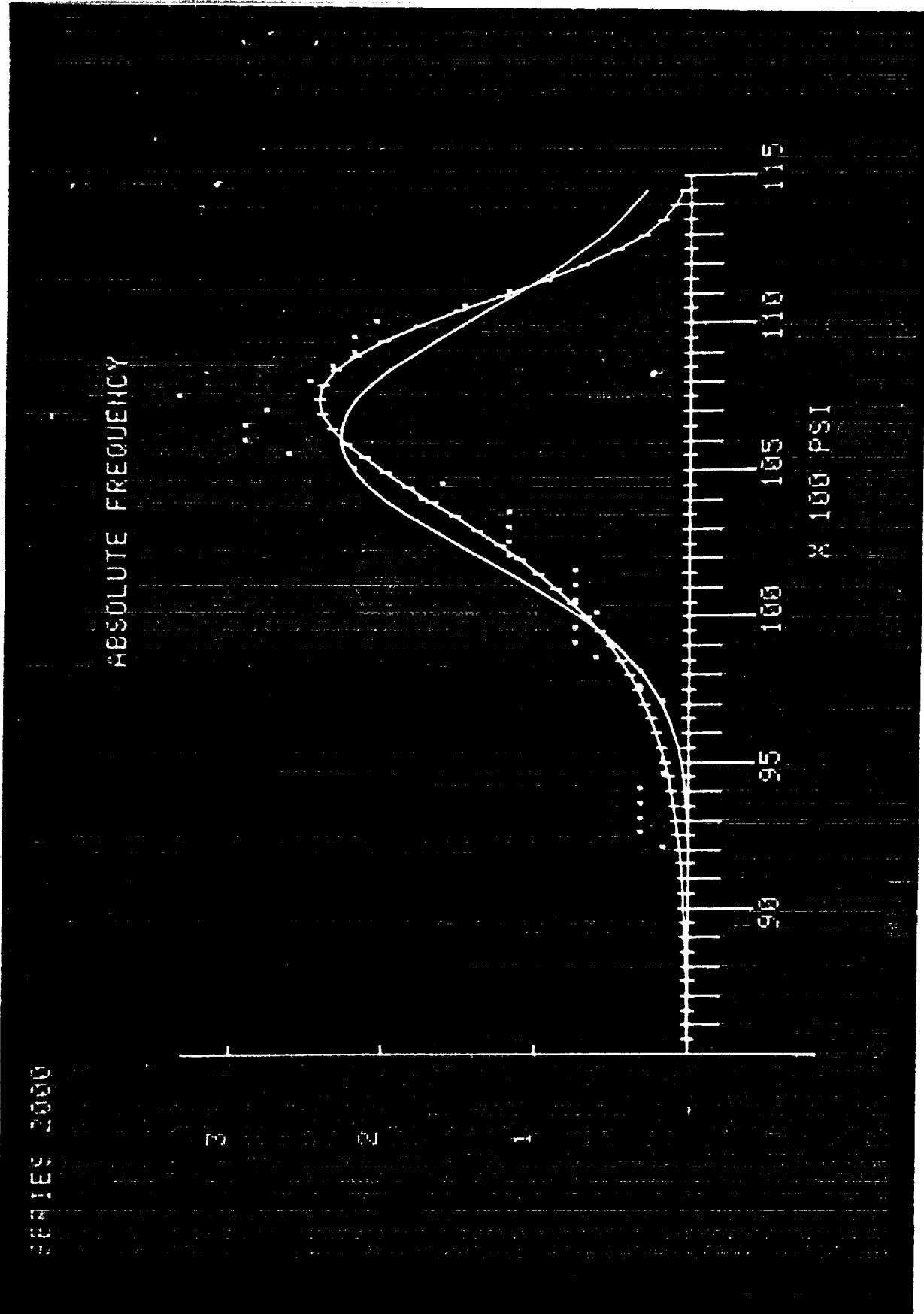
Series 11000: UNION CARBIDE MACC \$#0288498\$P/N795003-1  
PANEL 12" x 3" x 25 PLY LOT#261931 TASK III

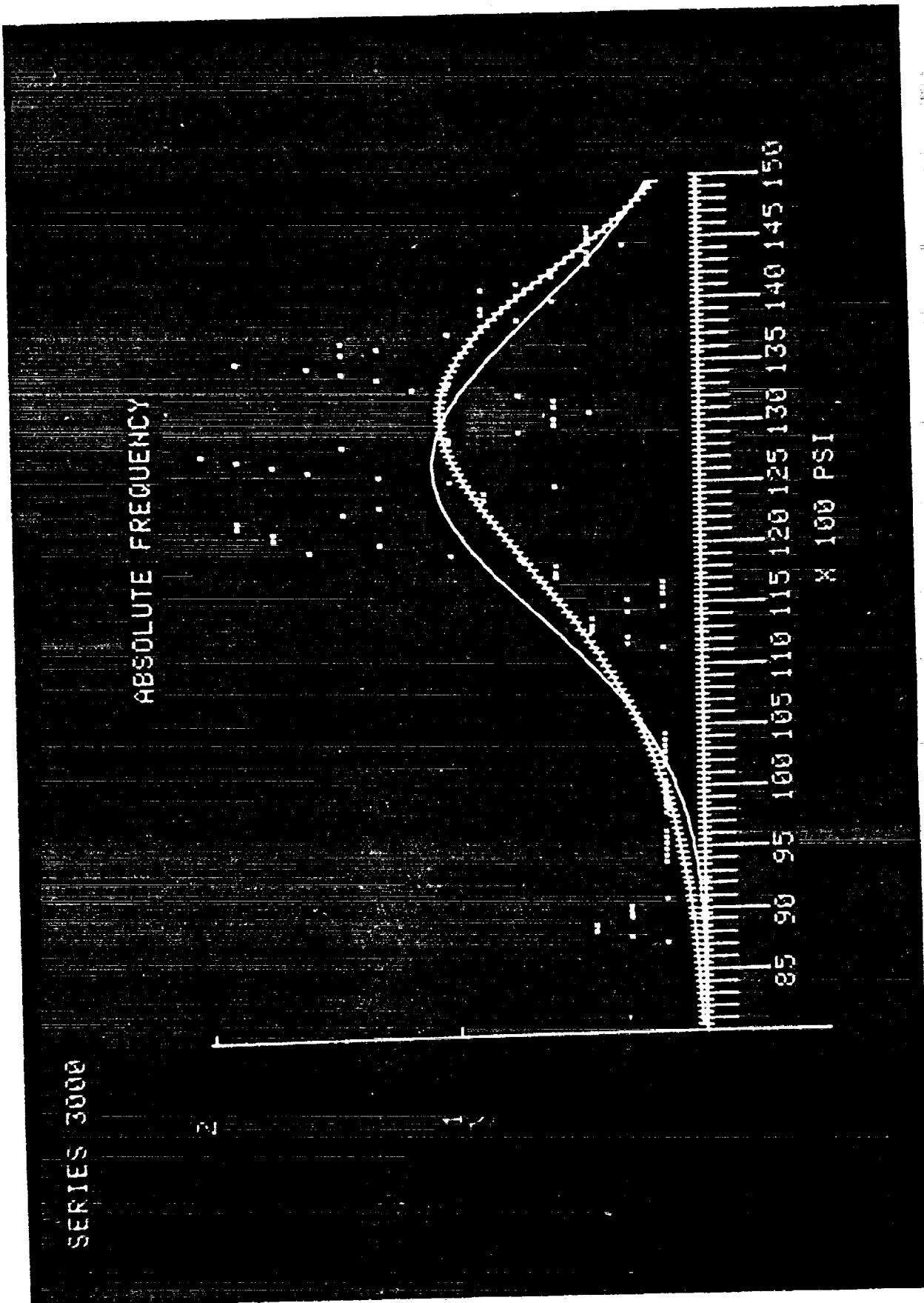
APPENDIX C  
GRAPHICAL REPRESENTATION OF SHEAR STRENGTH DATA

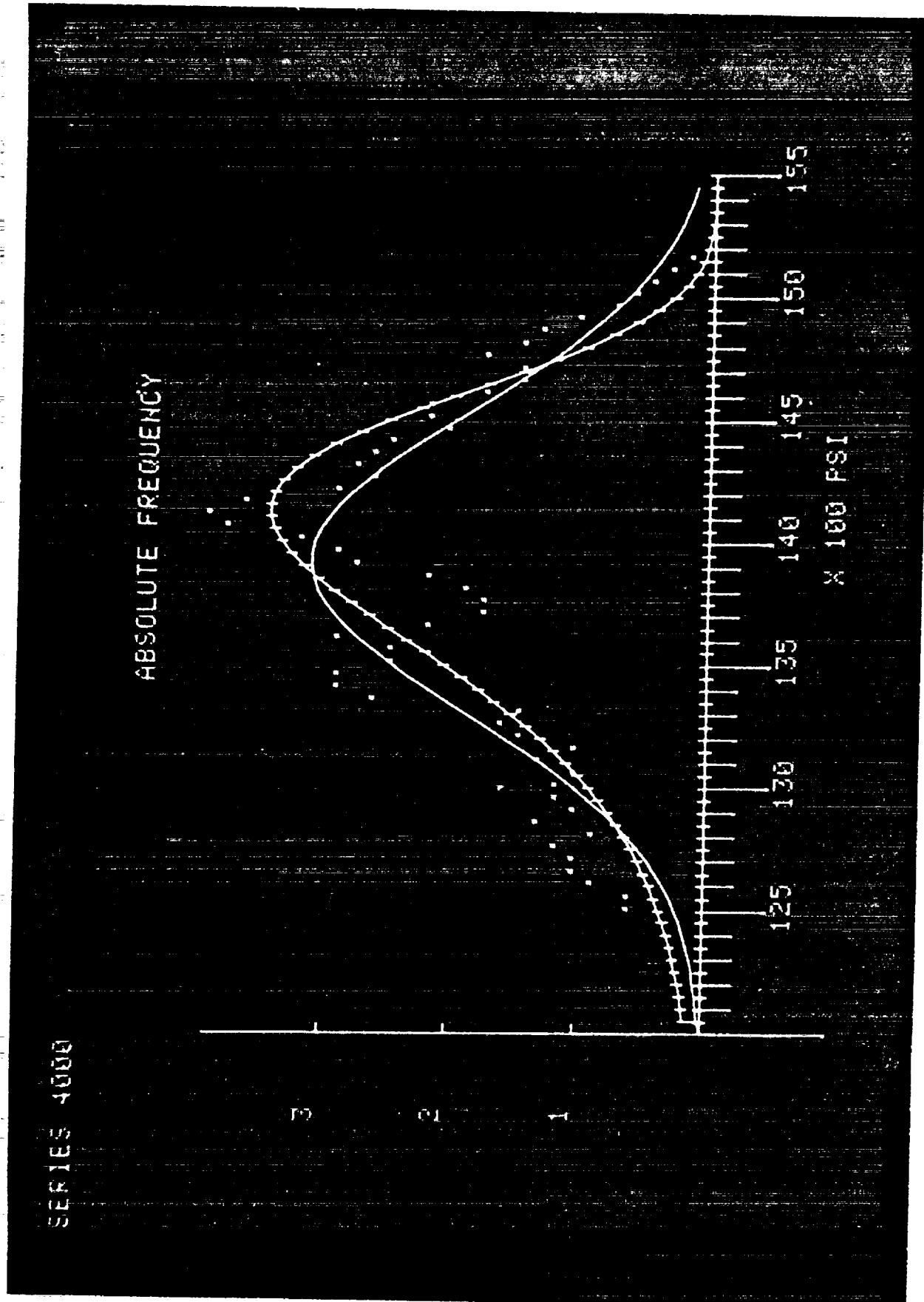
- Section I.      Absolute Frequency Distributions
- Section II.     Absolute & Cumulative Histograms
- Section III.    Absolute & Cumulative Moving Averages
- Section IV.     Calculated Distribution Comparisons
- Section V.      Extreme Value Comparisons

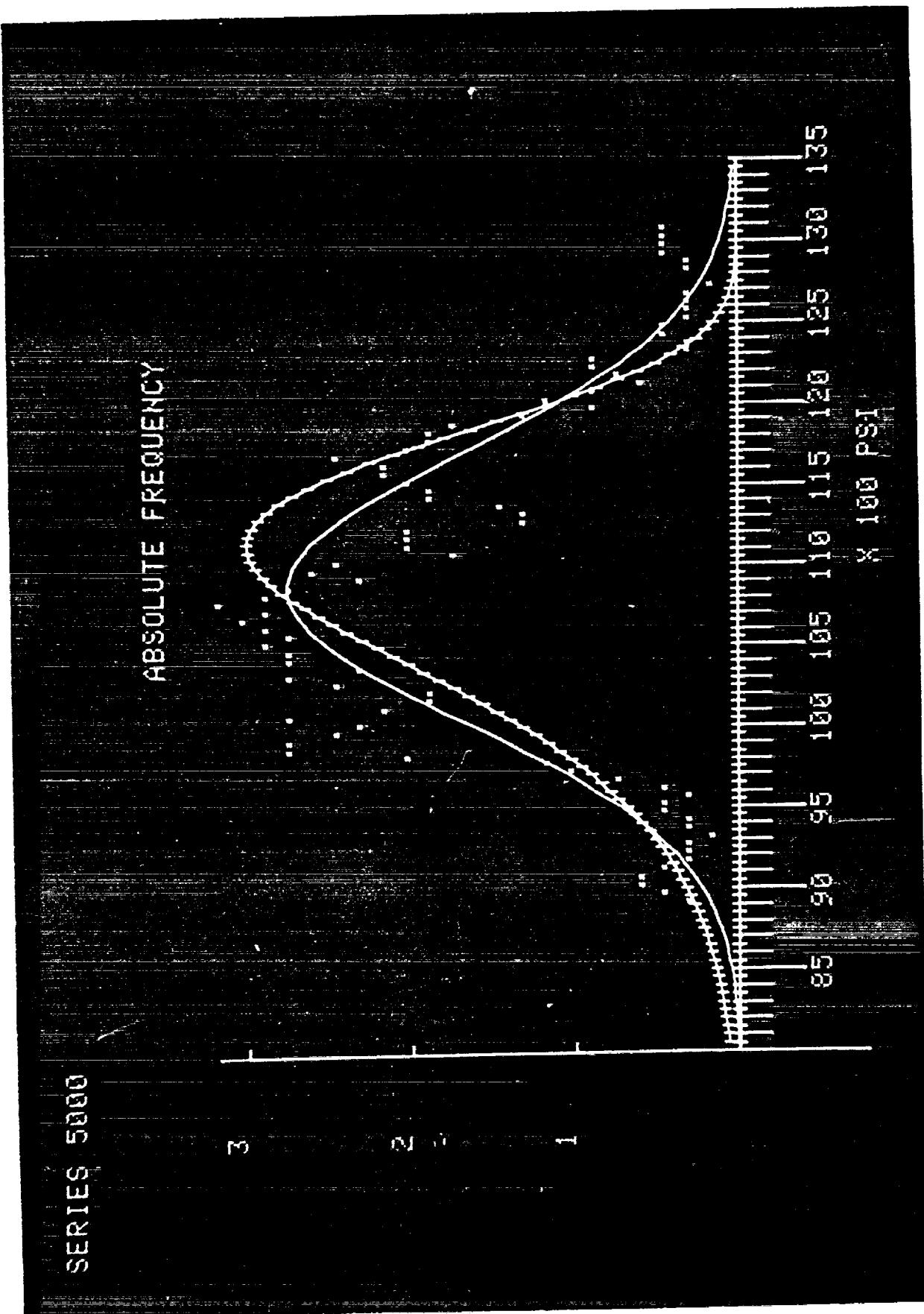
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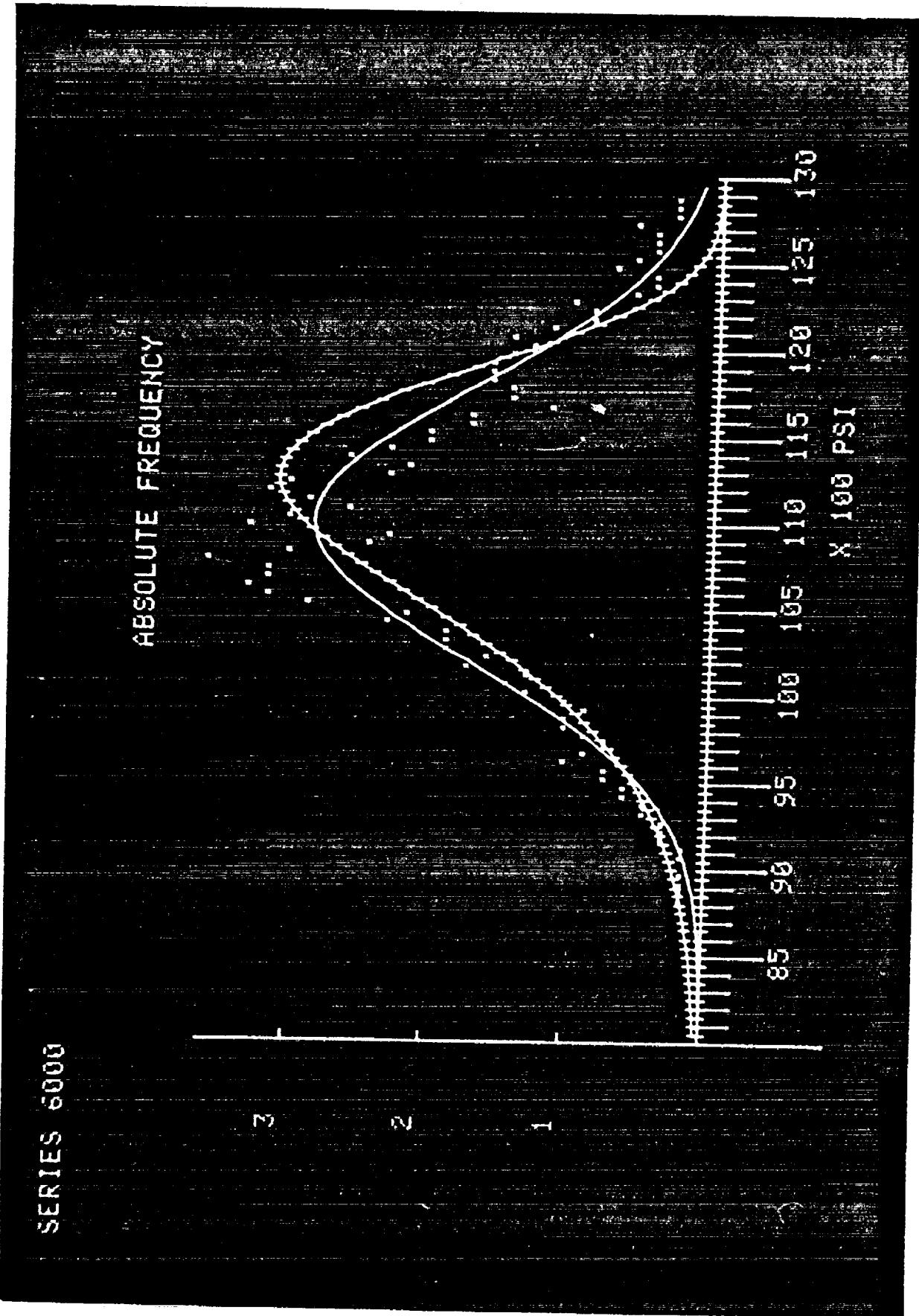


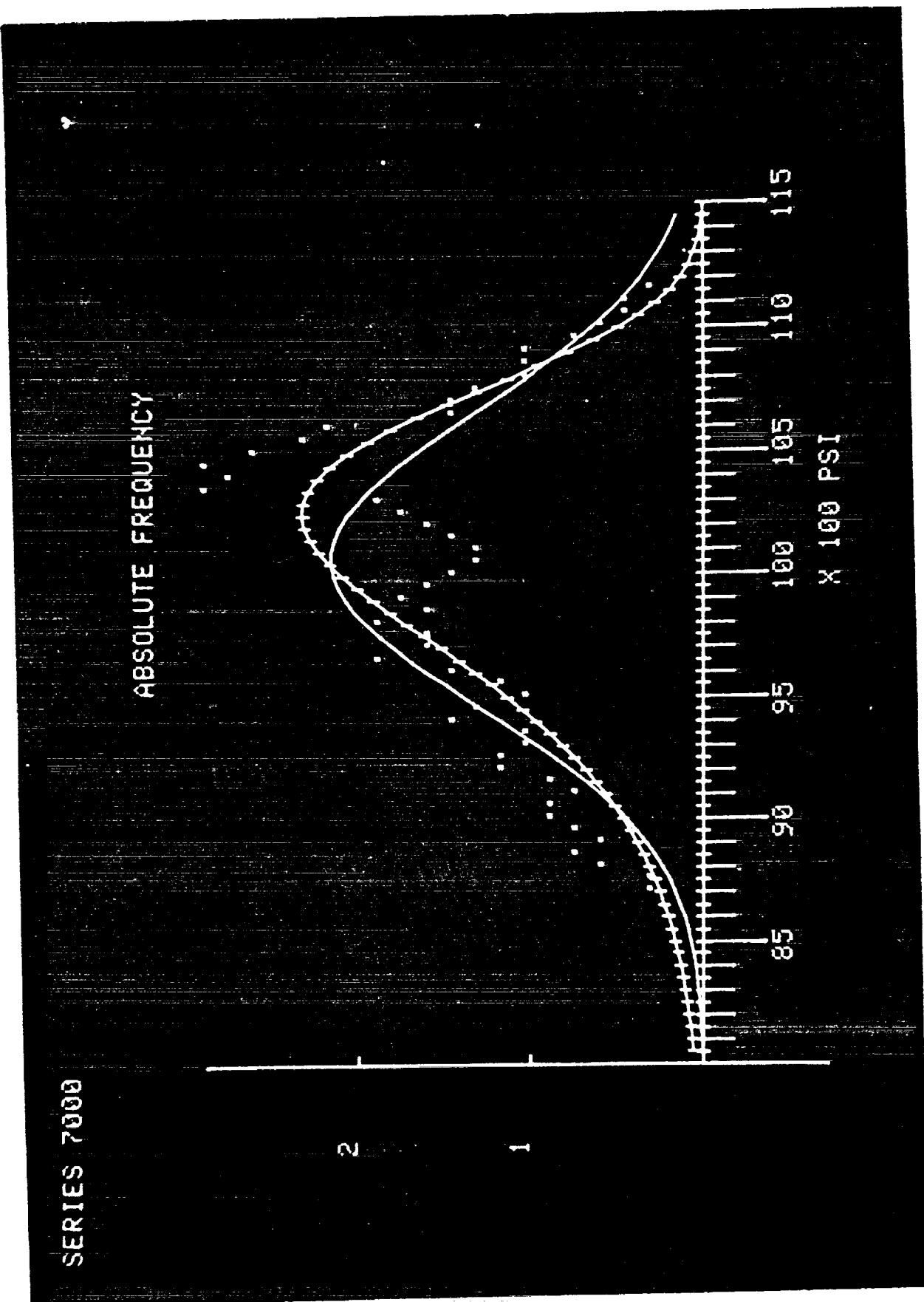


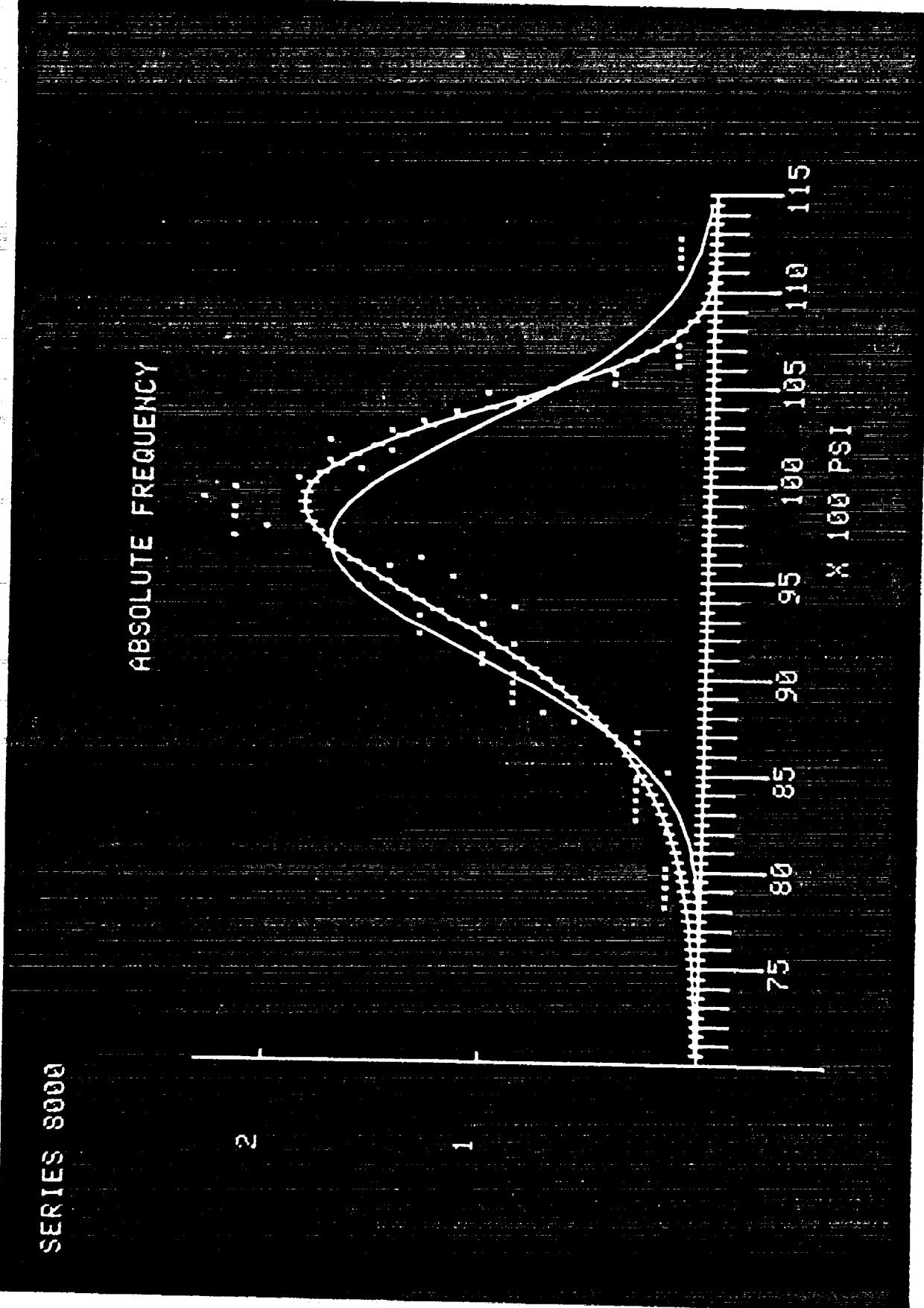


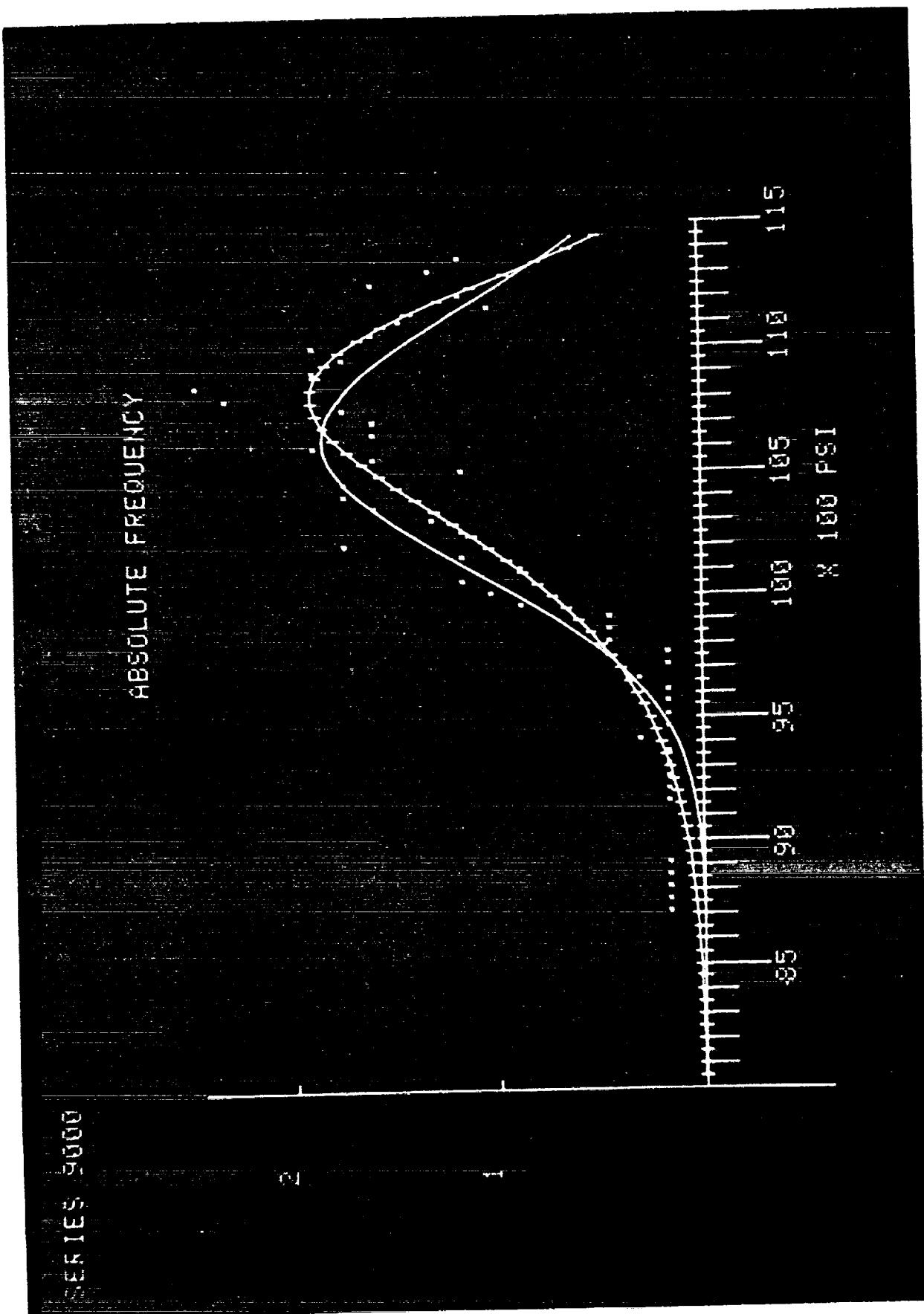


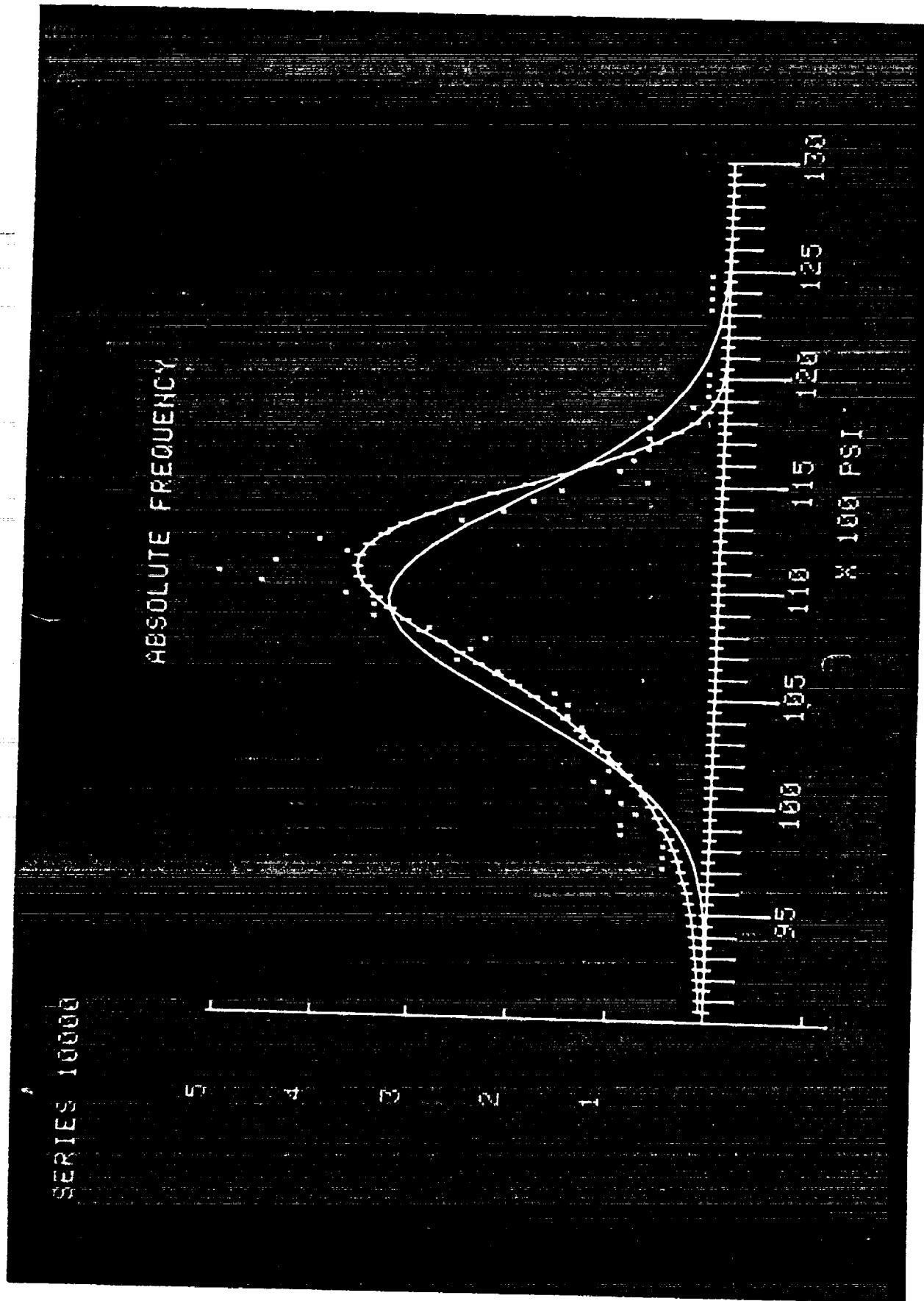


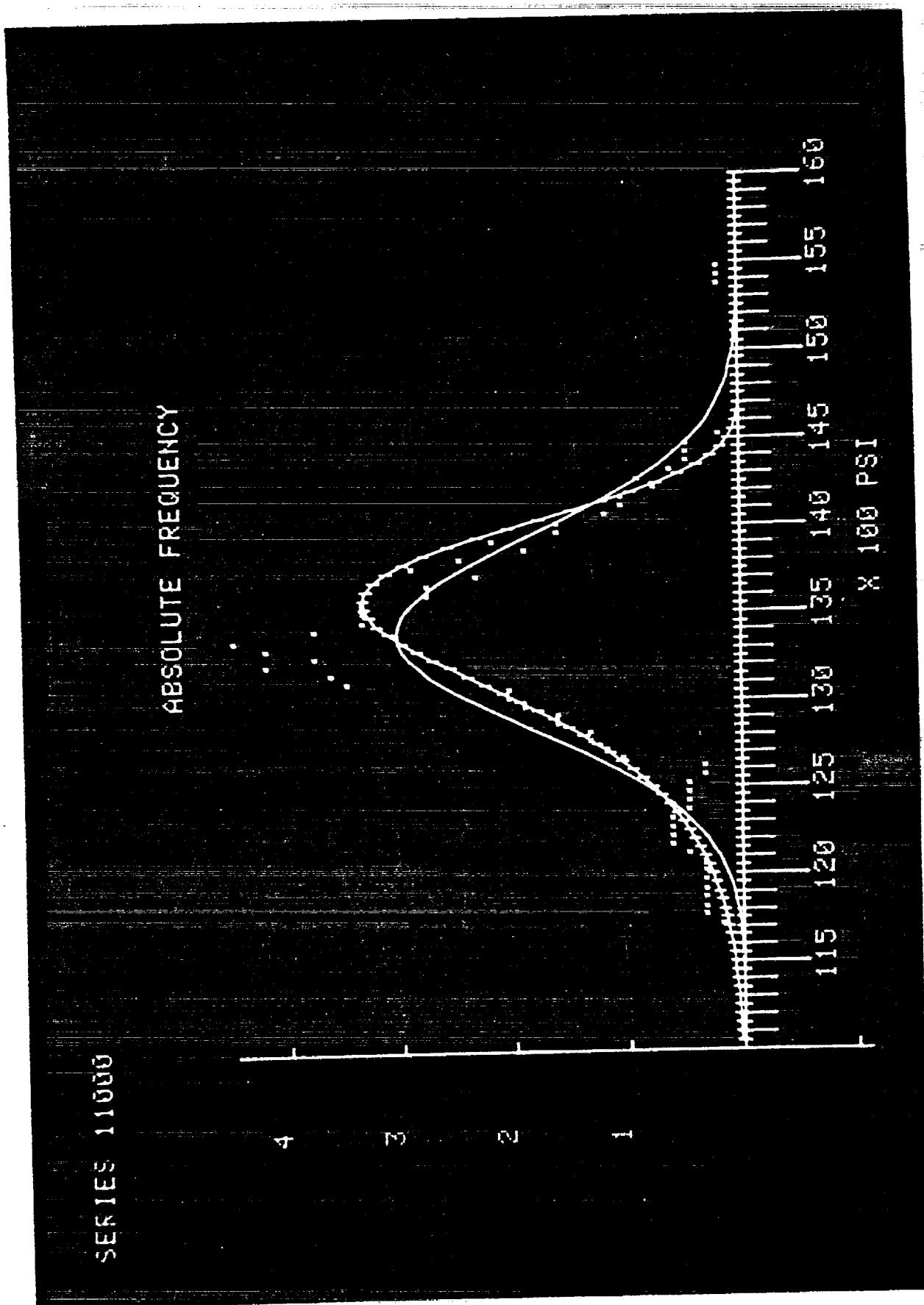




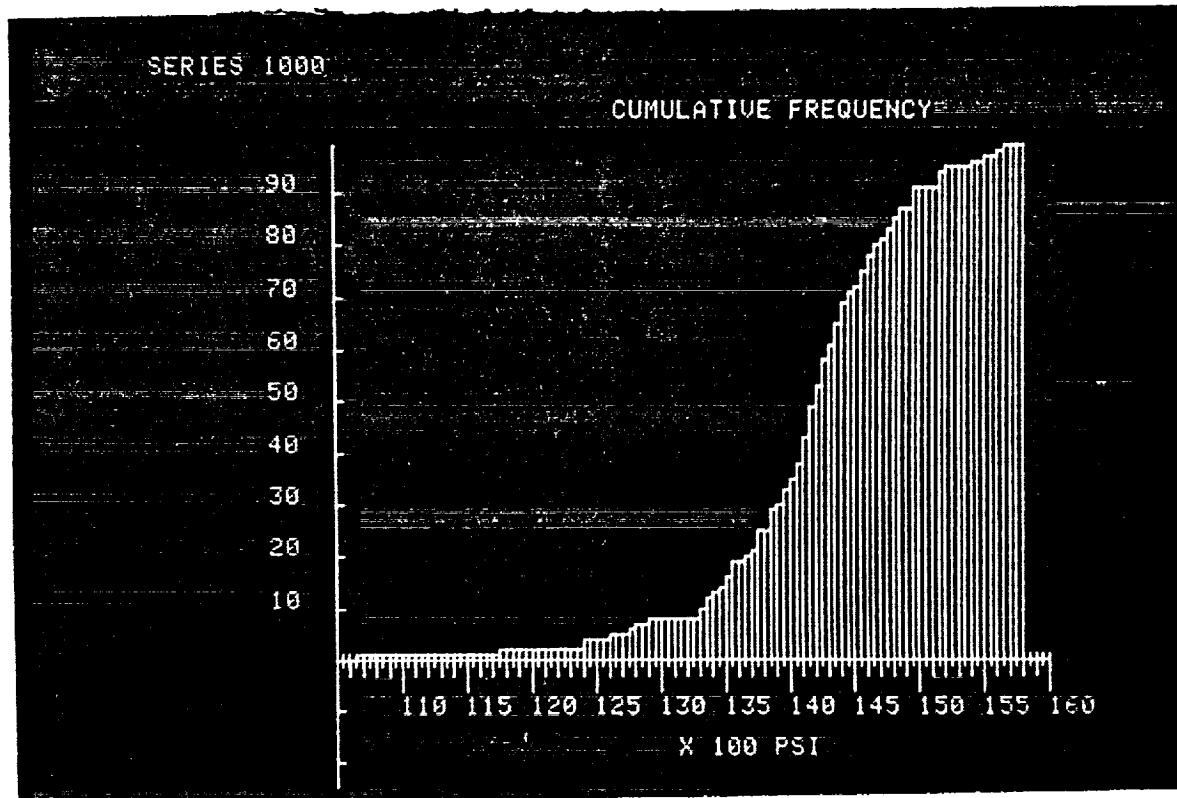
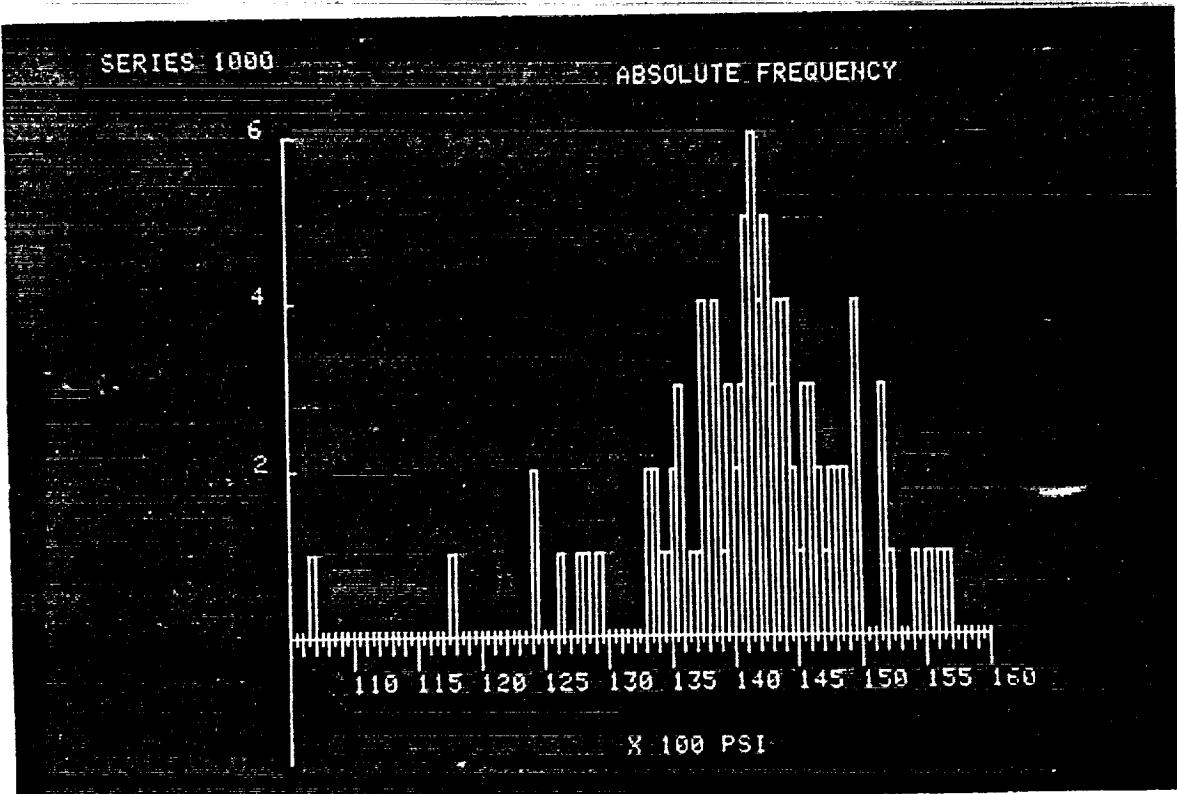


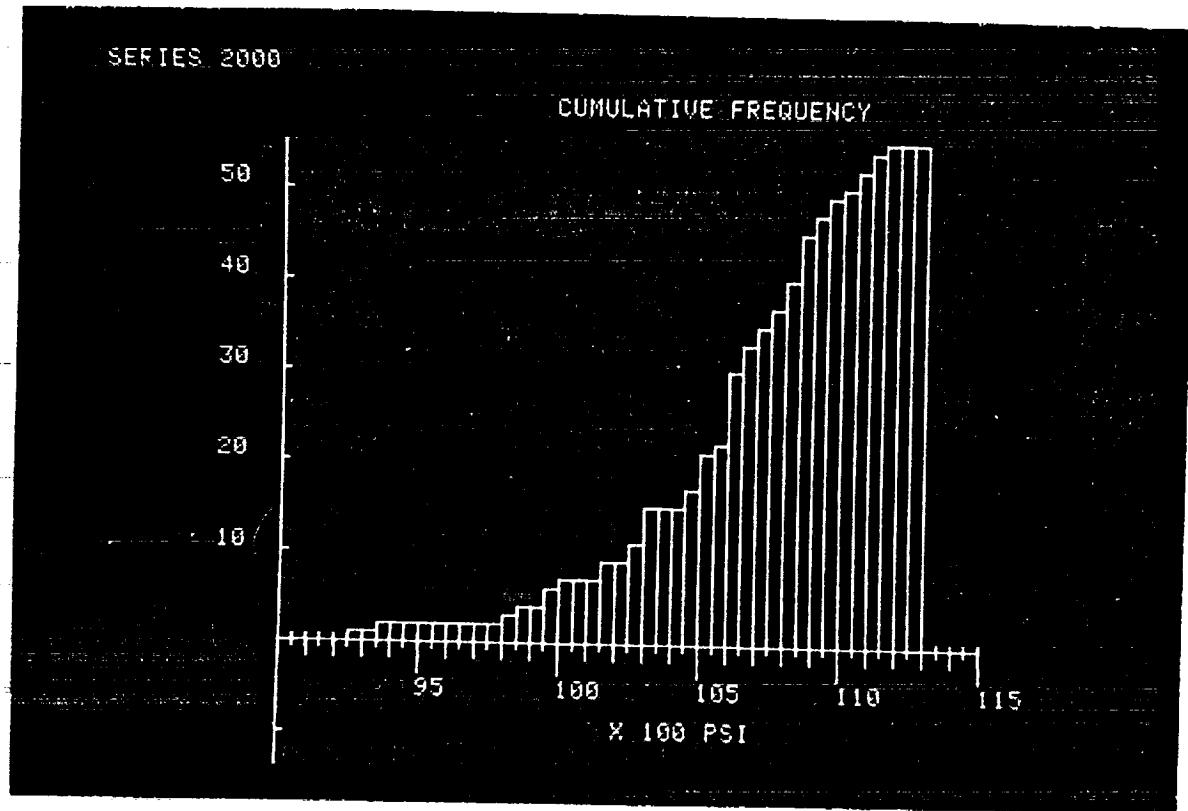
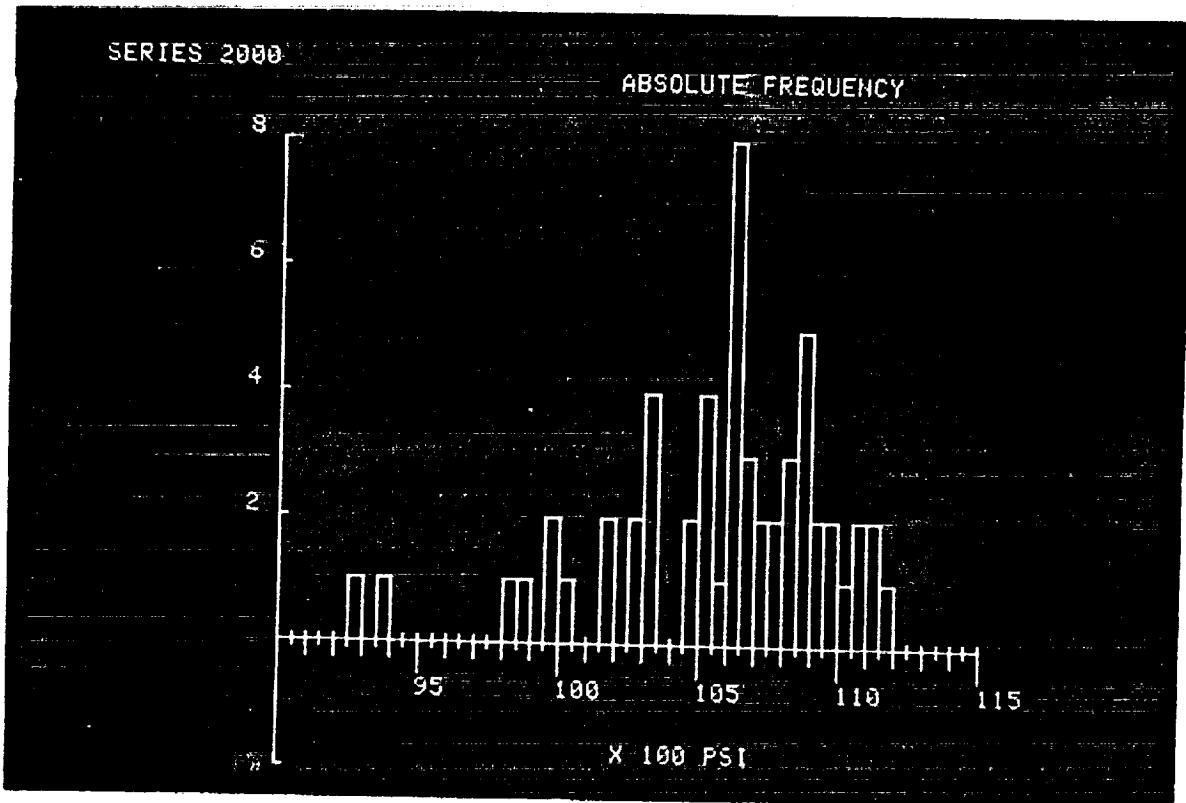


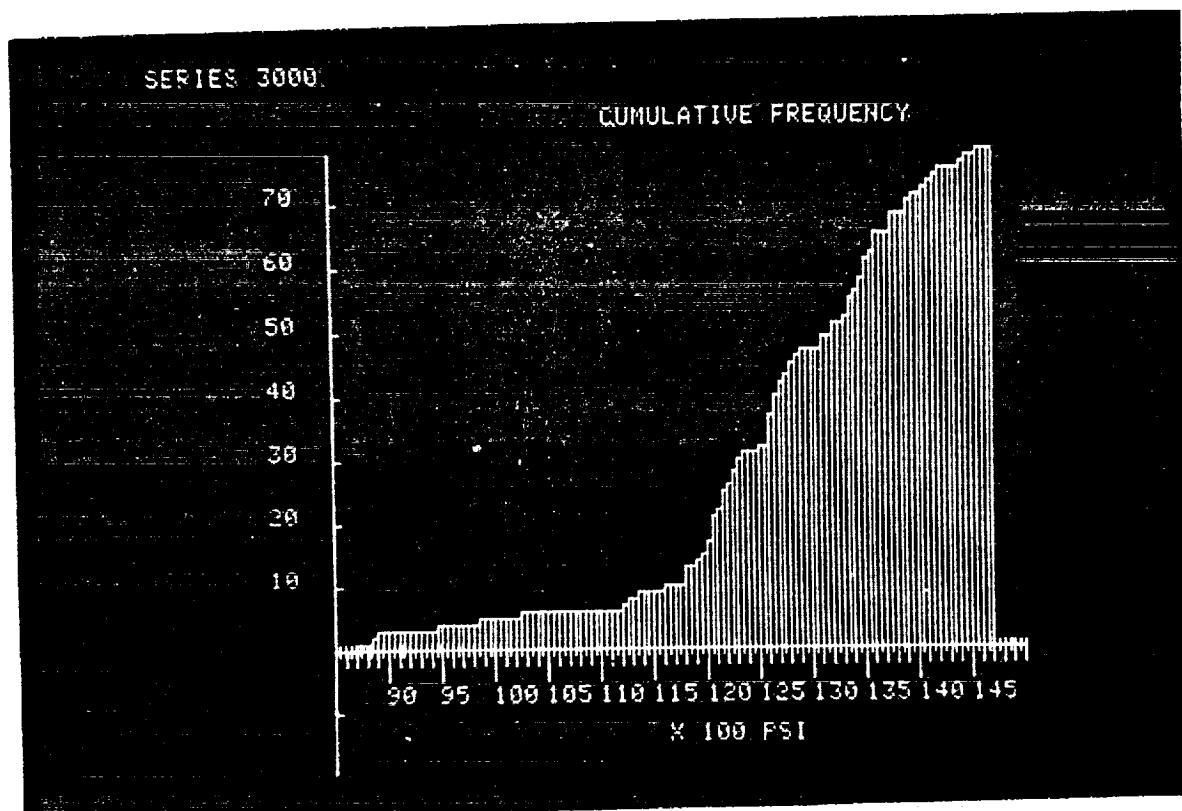
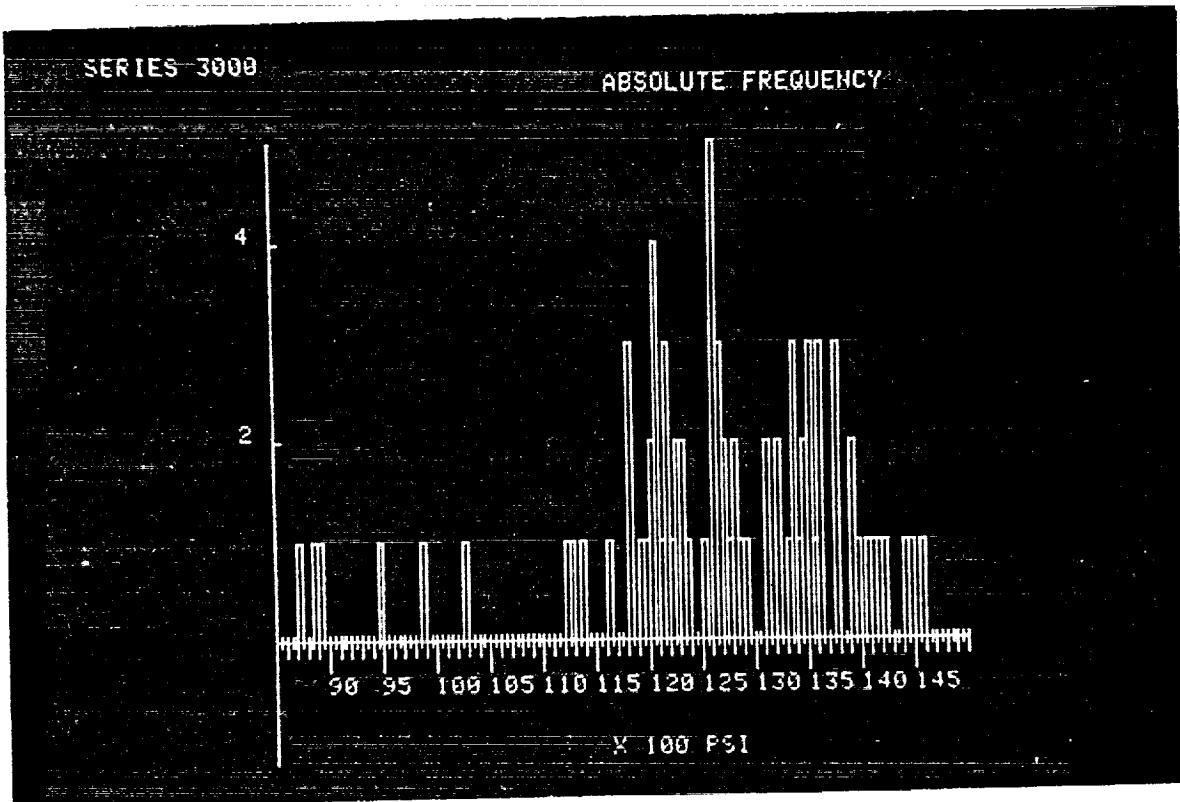


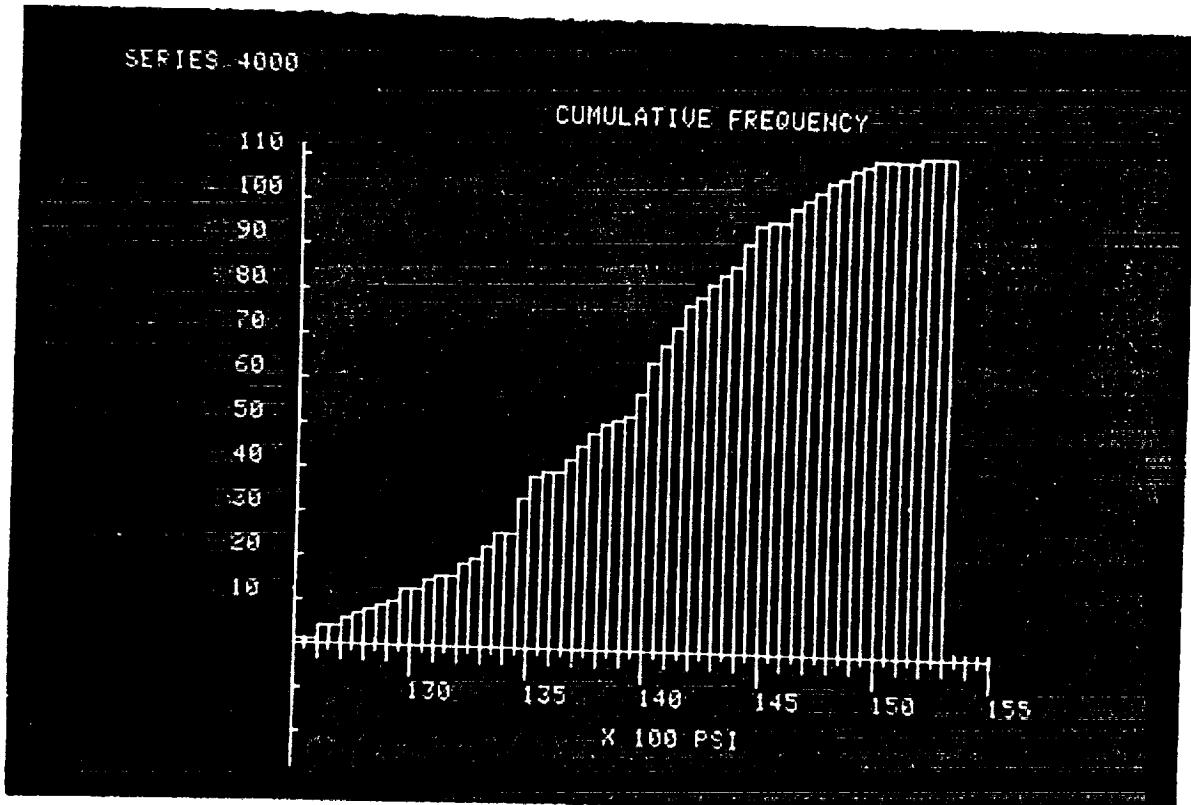
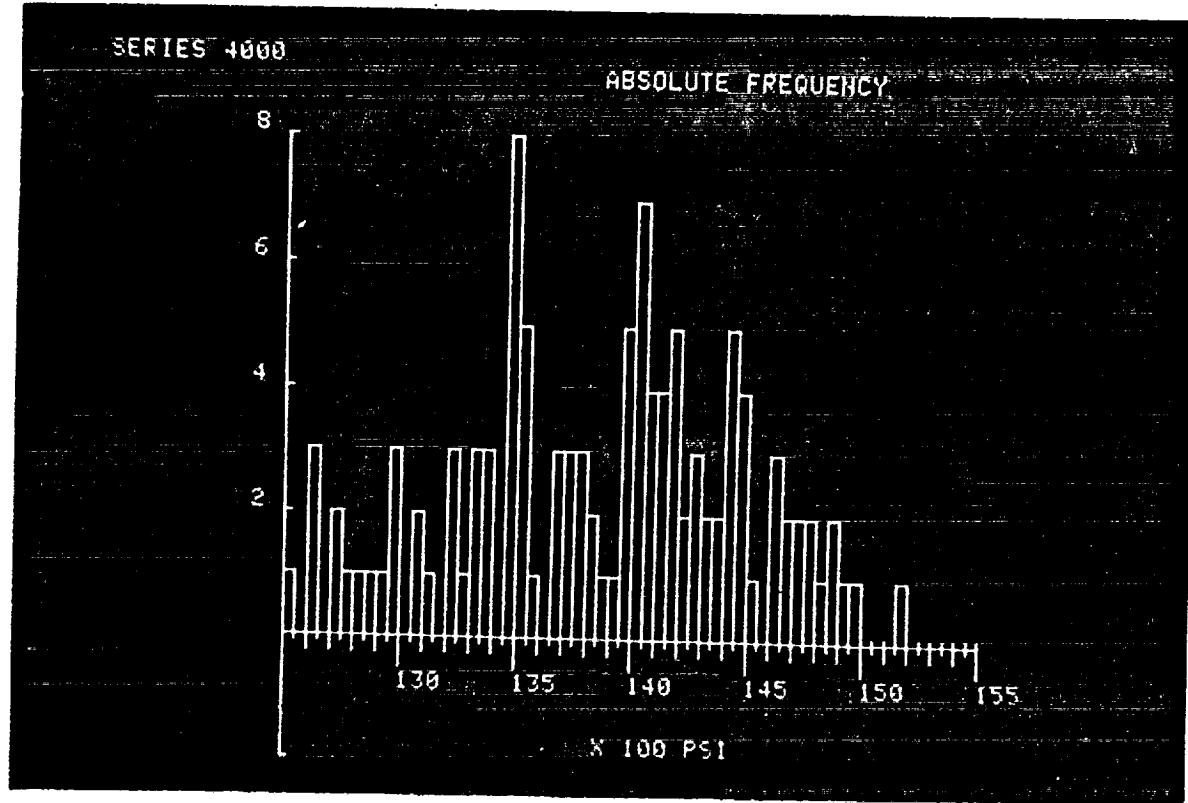


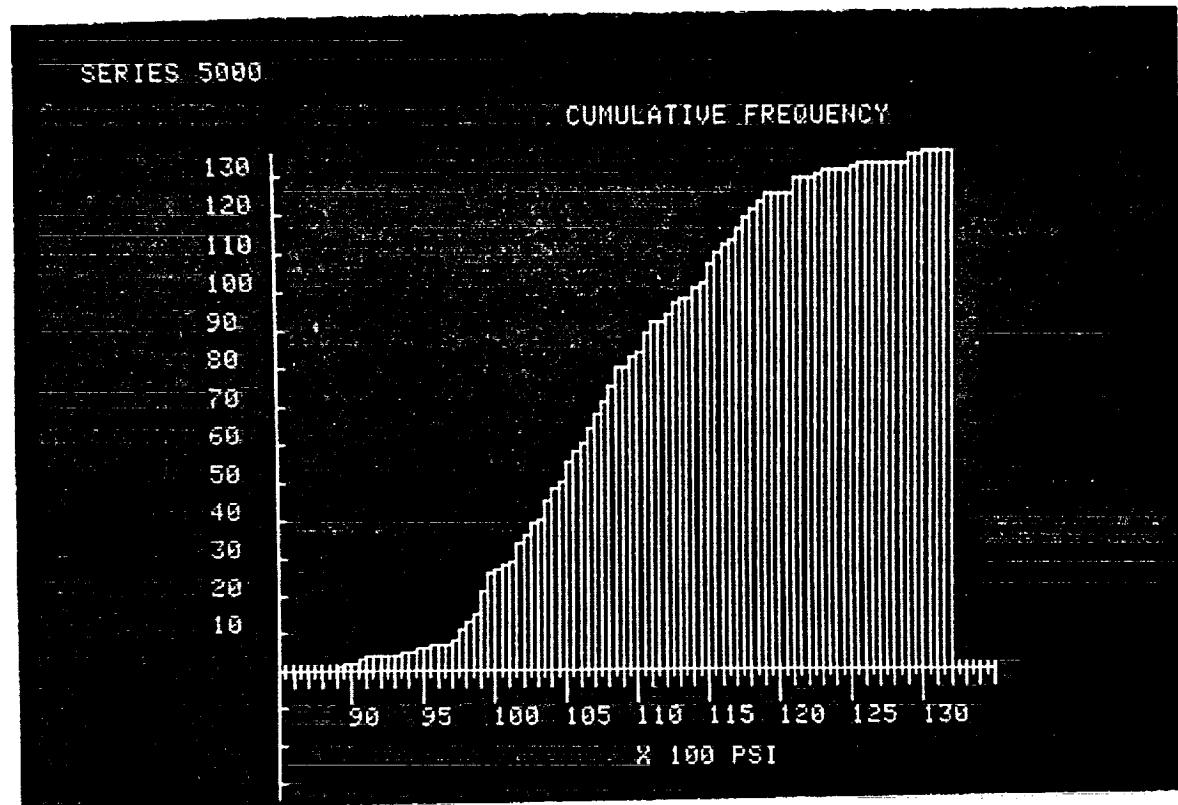
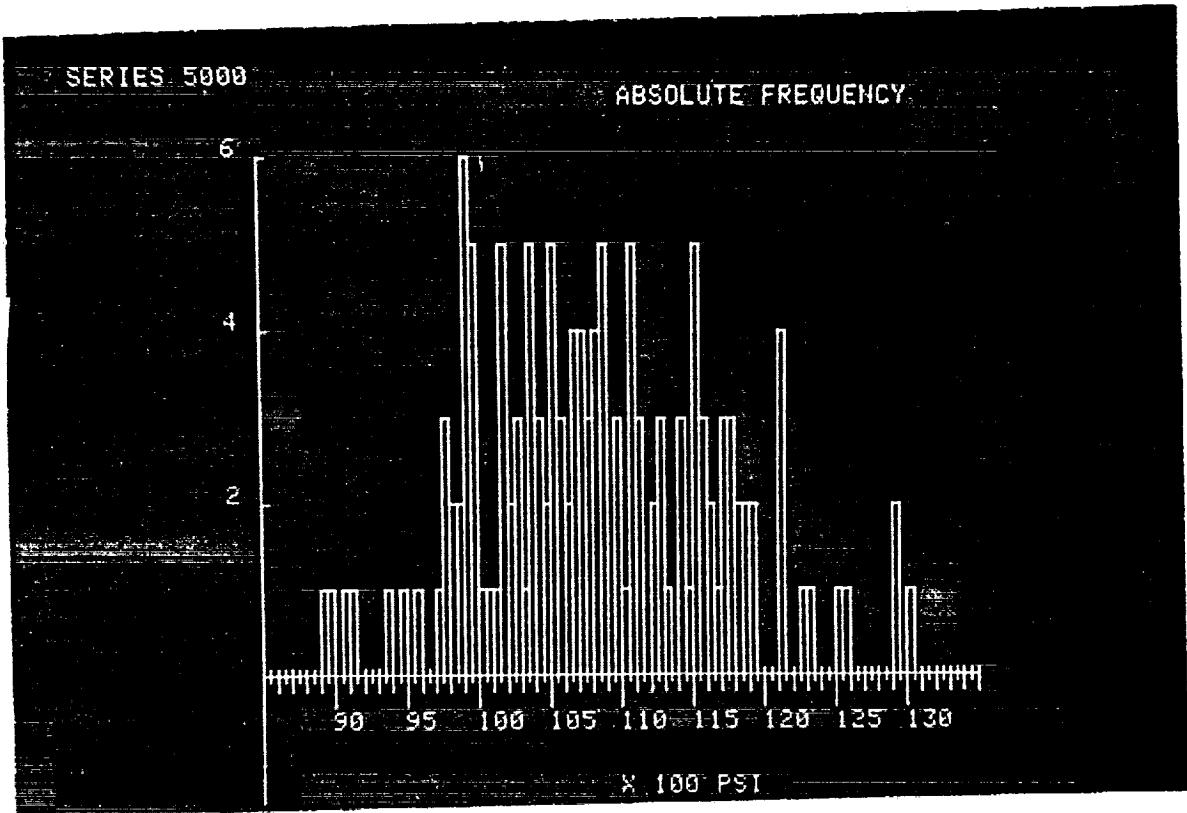
**SECTION II.**

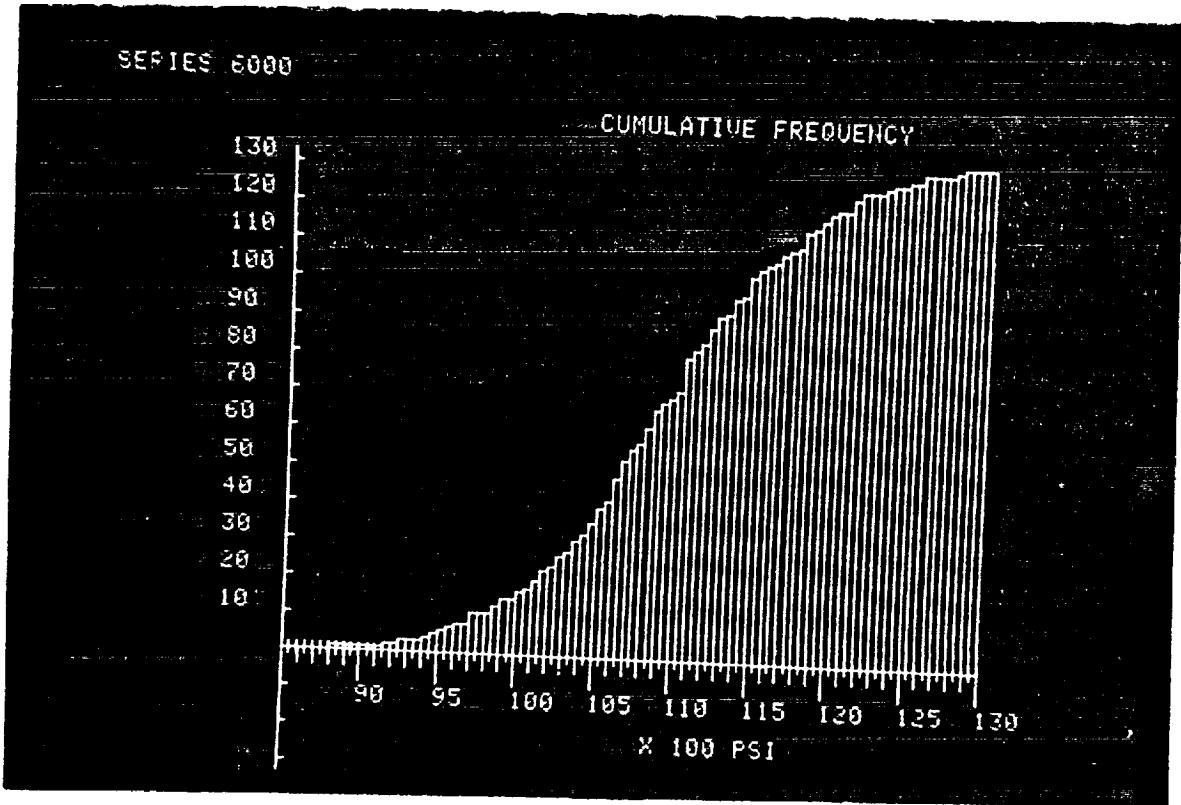
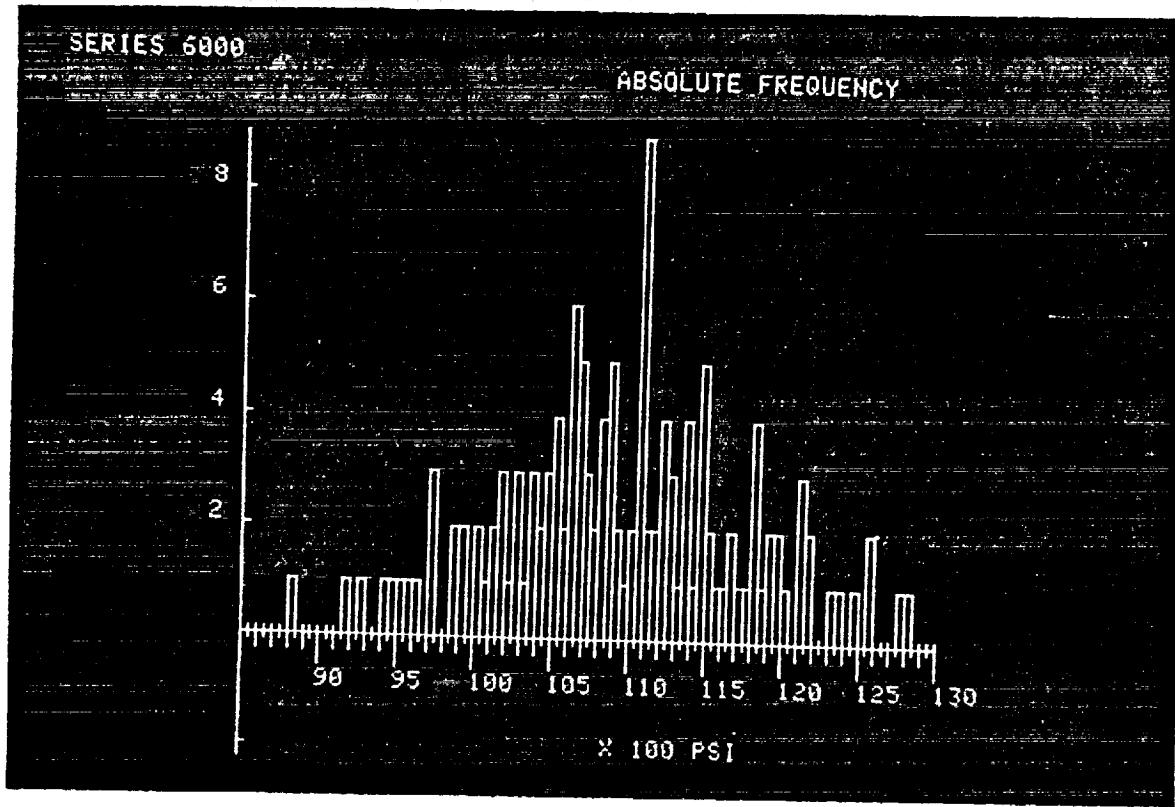


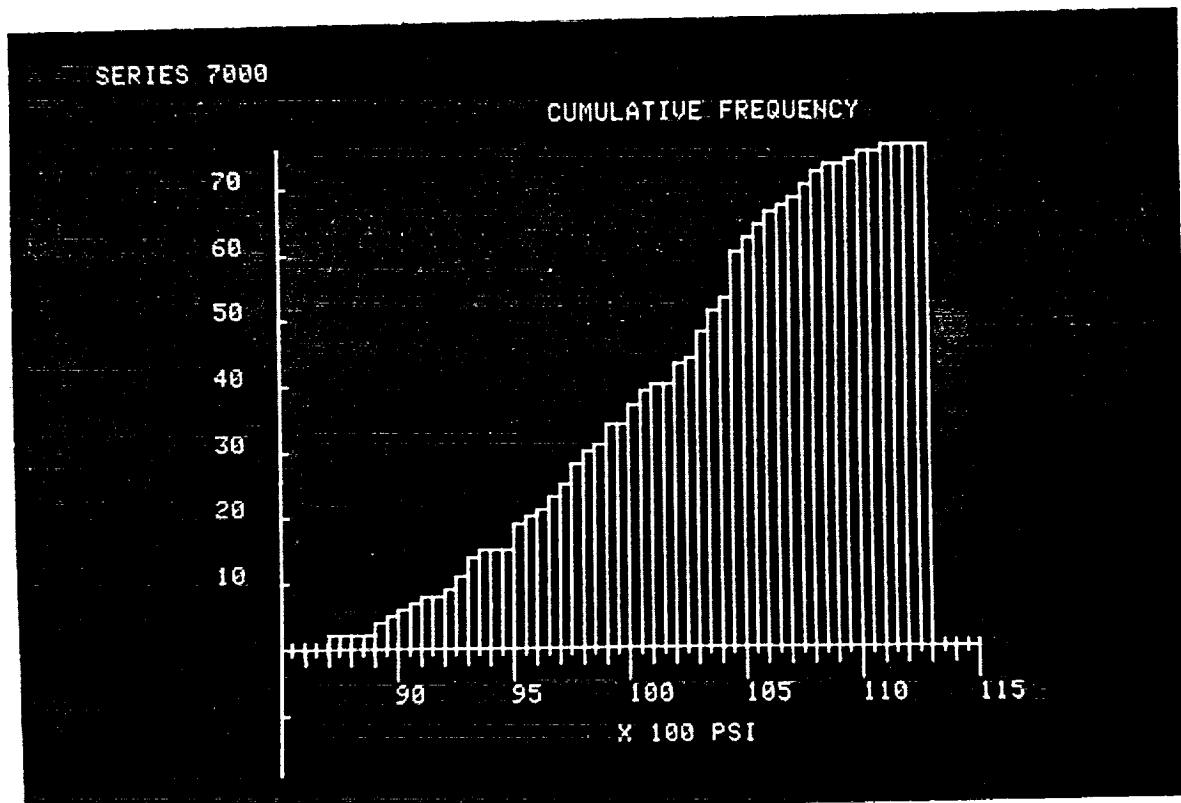
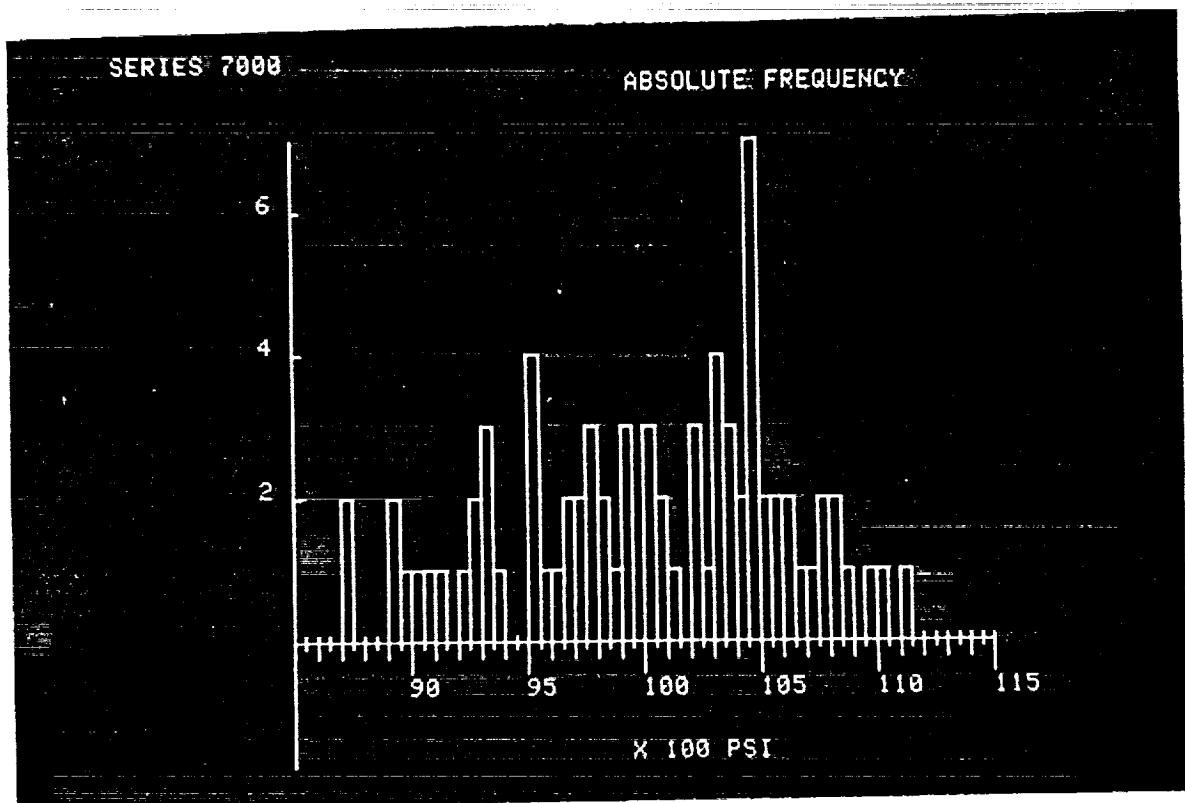


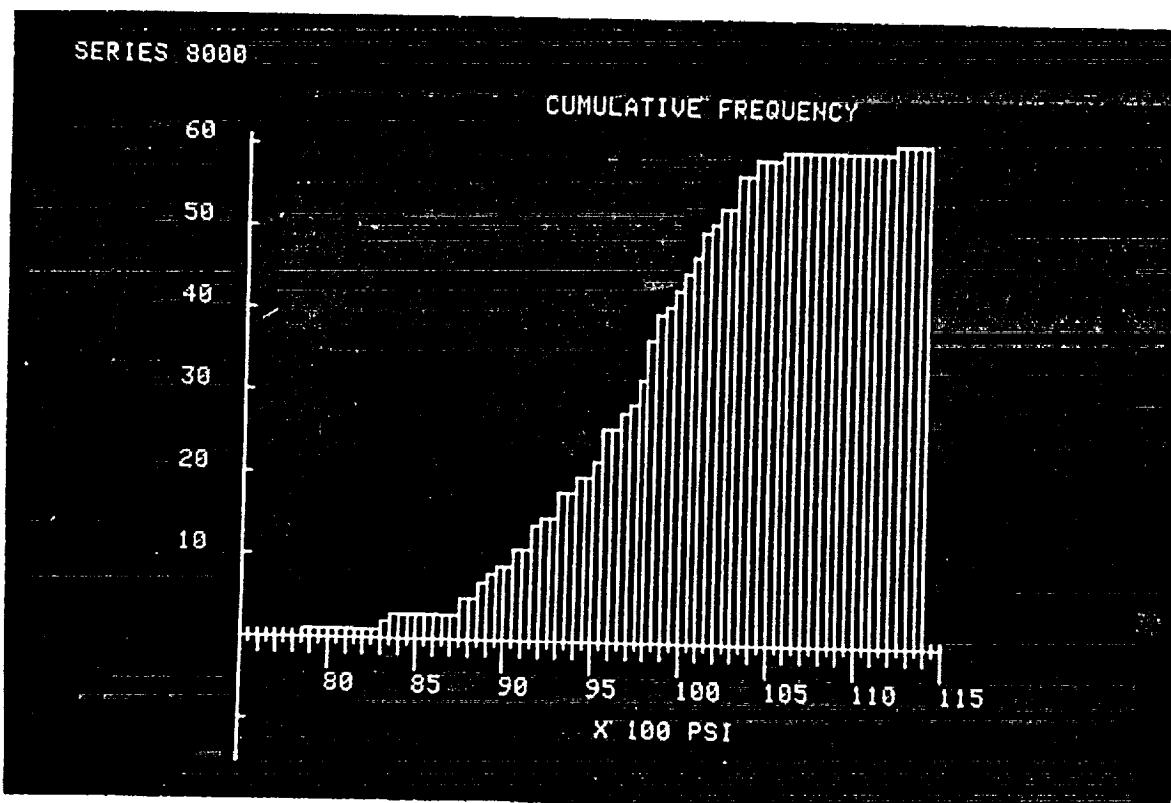
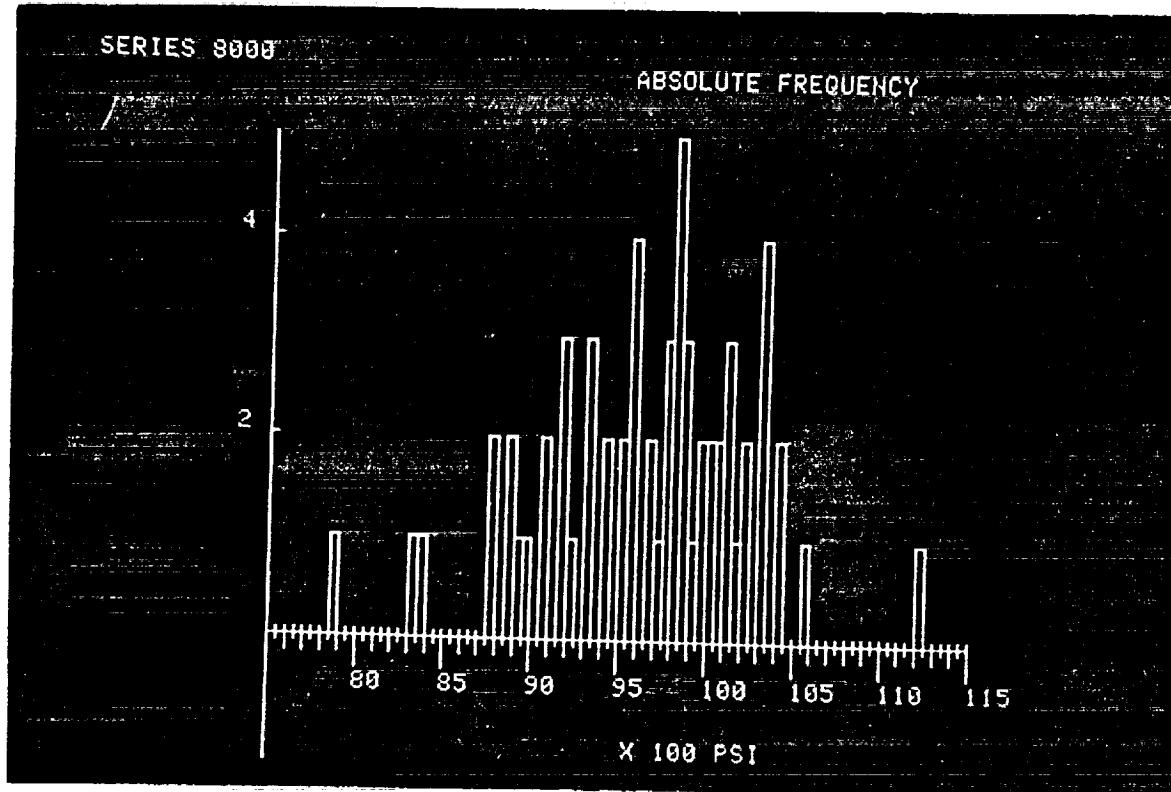


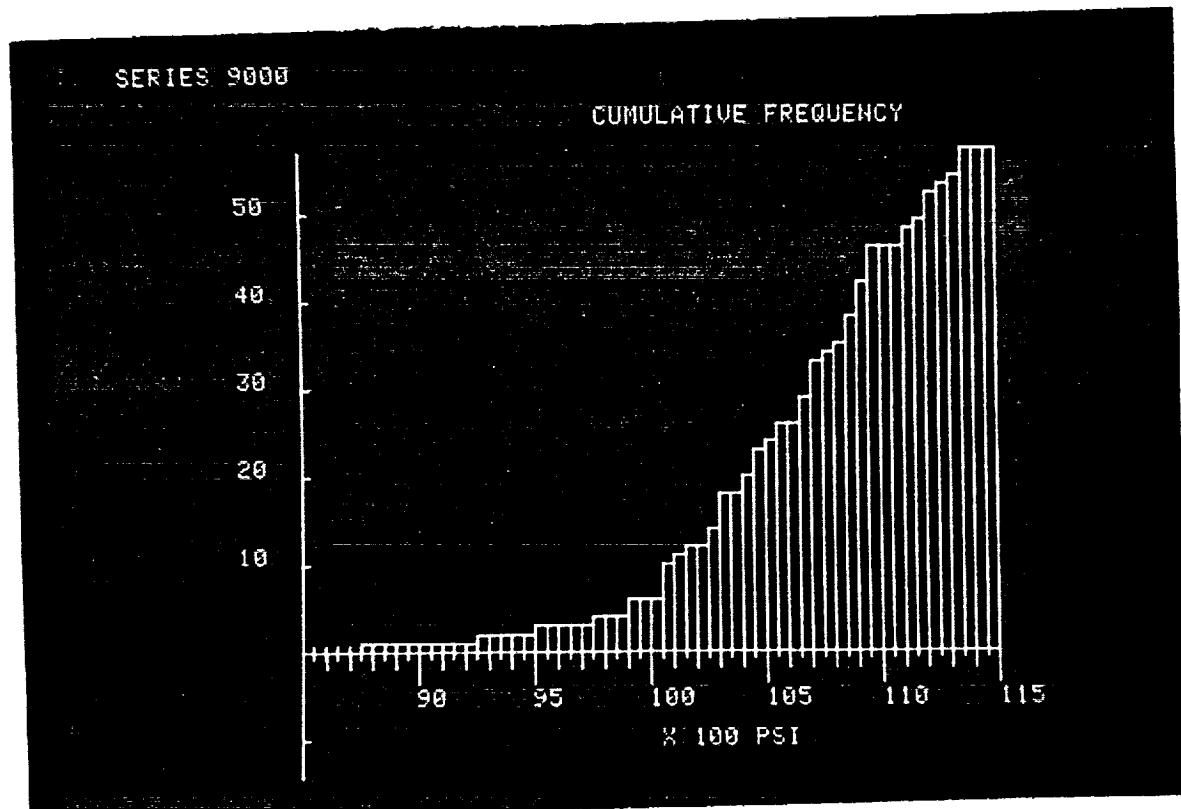
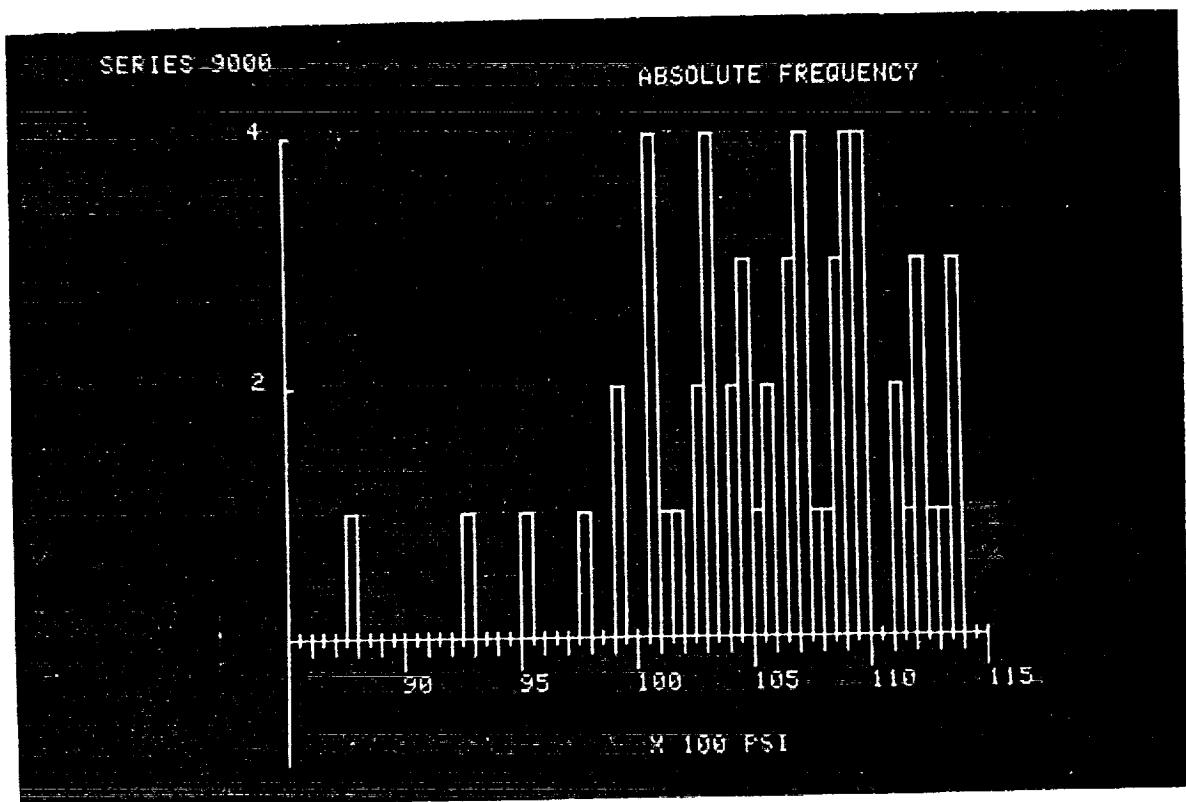


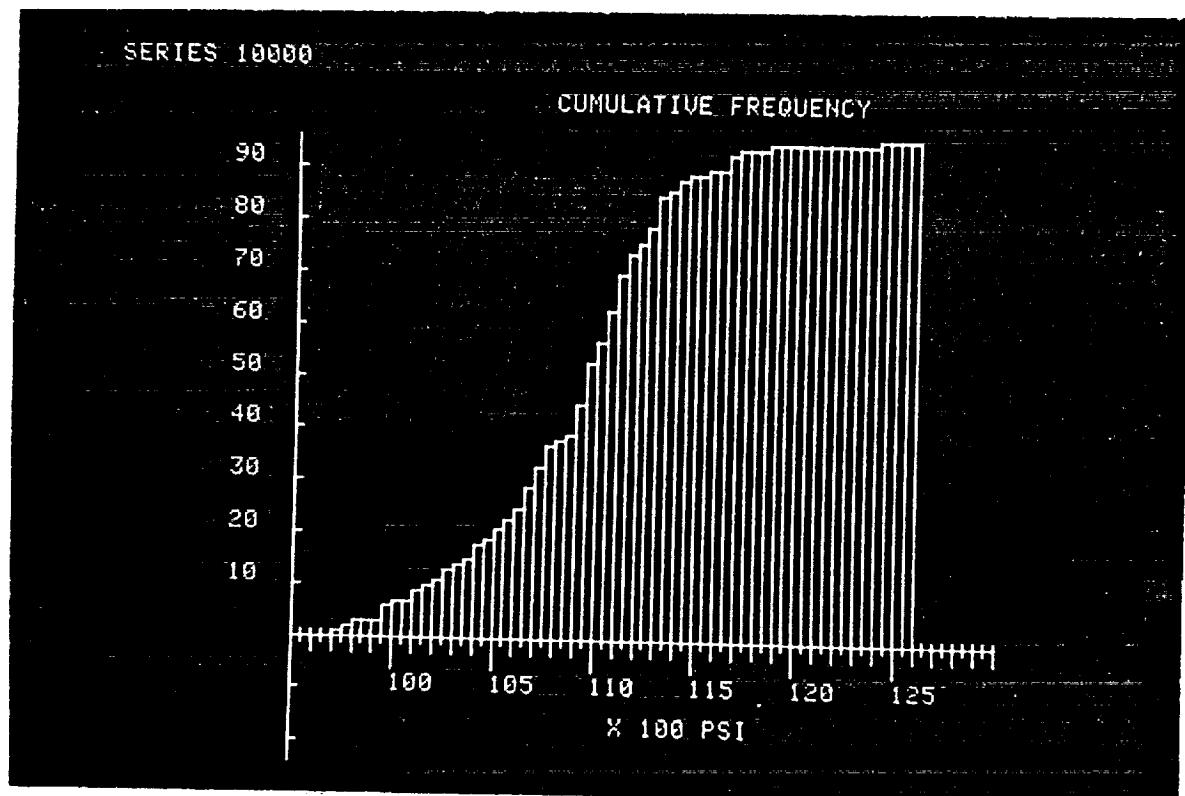
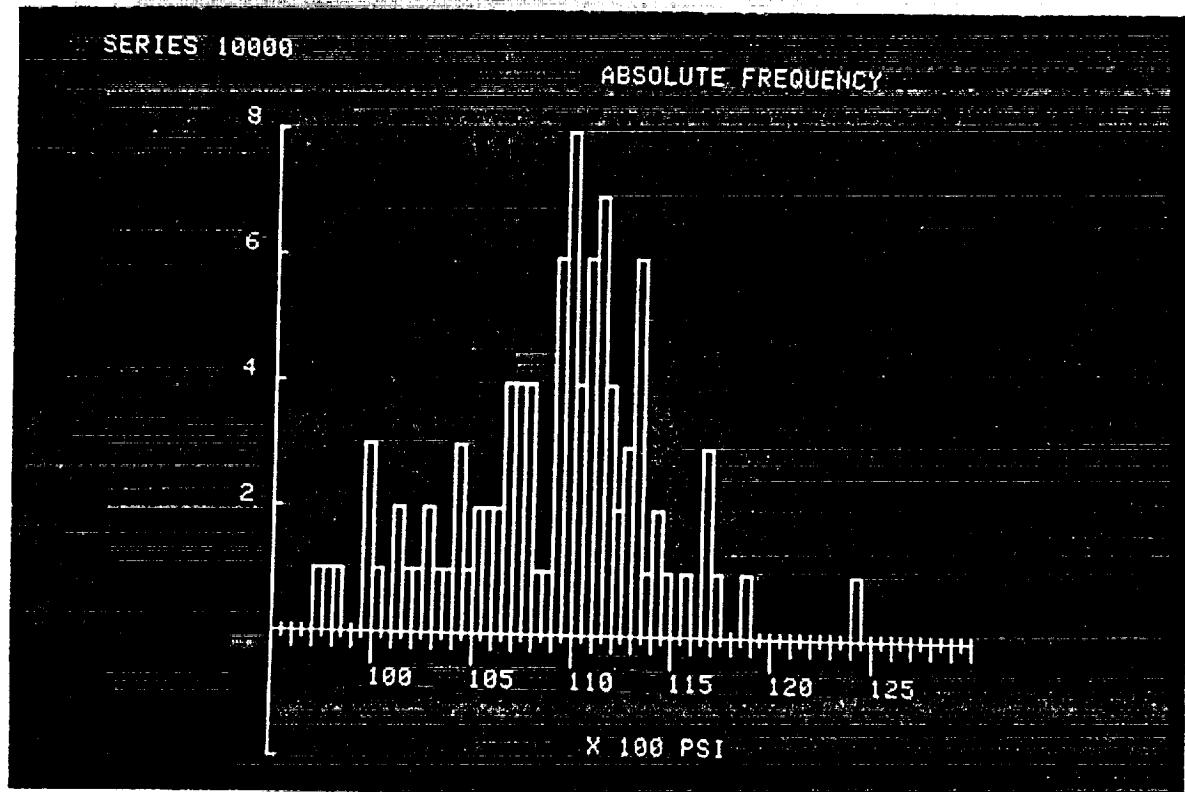


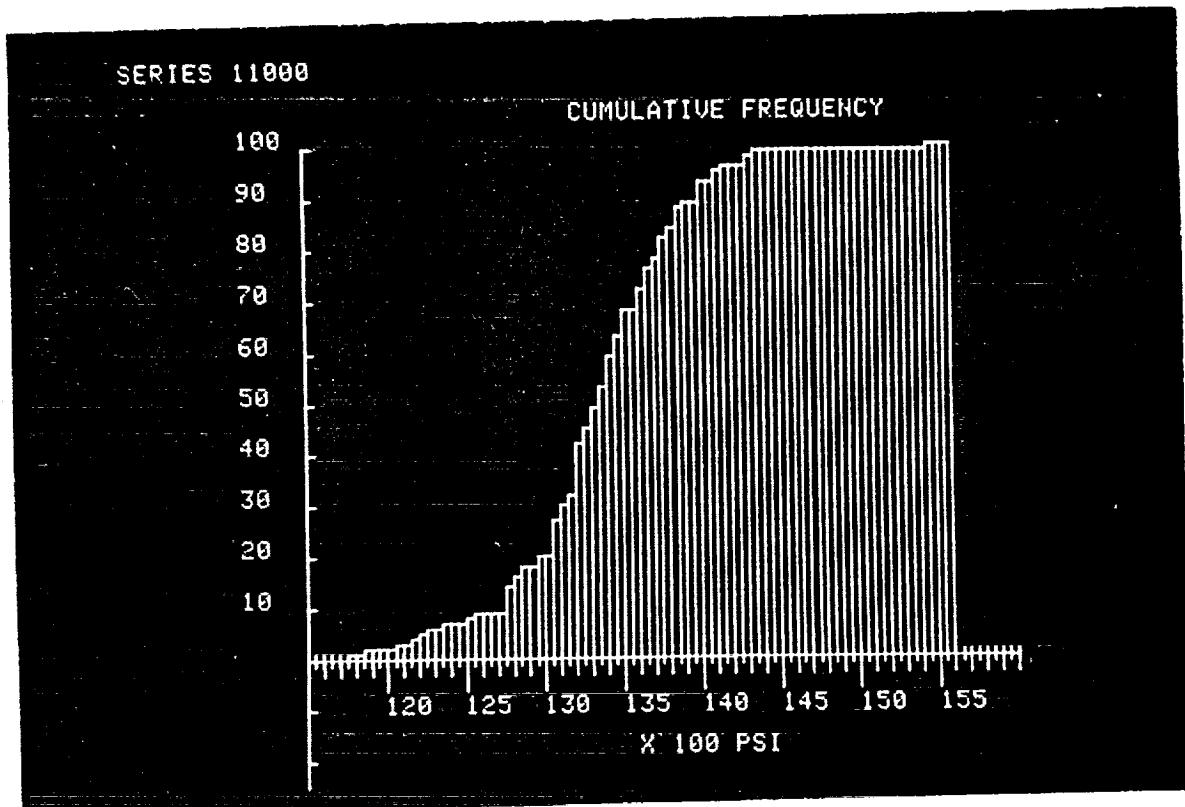
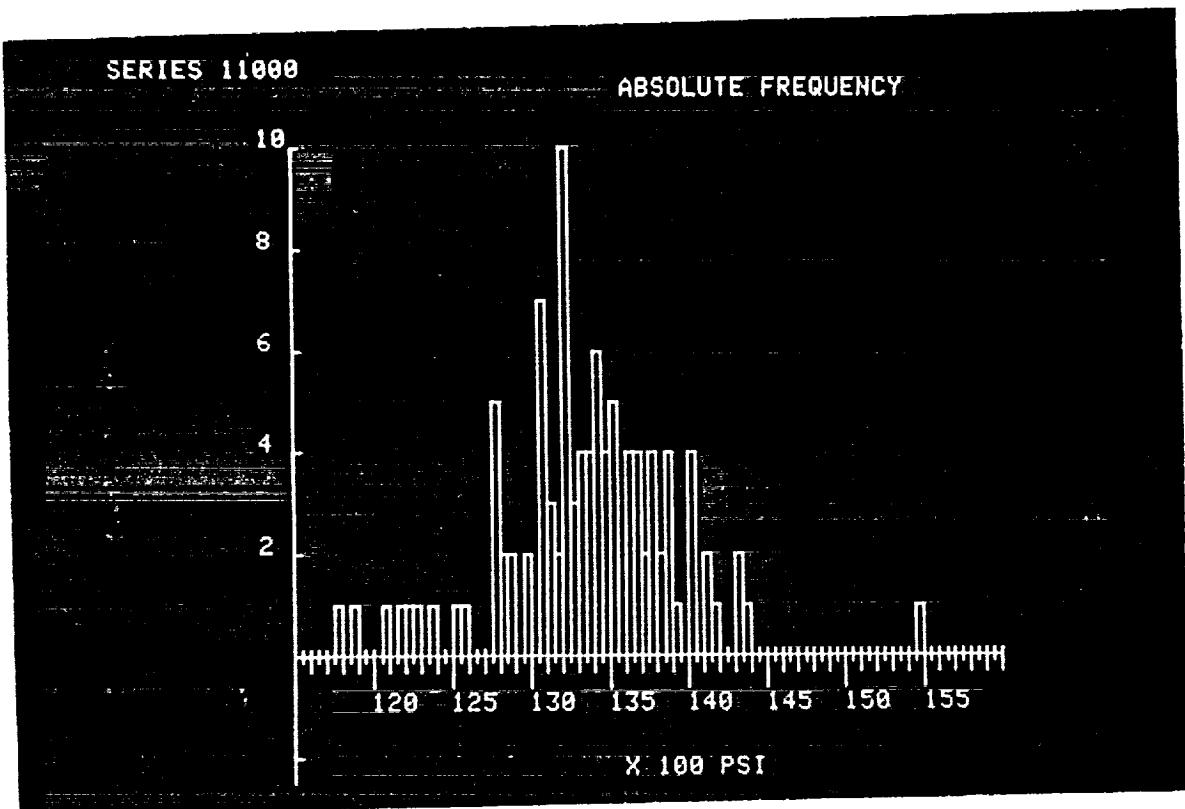












**SECTION III.**

SERIES 1000

ABSOLUTE FREQUENCY  
(Moving Average)

2

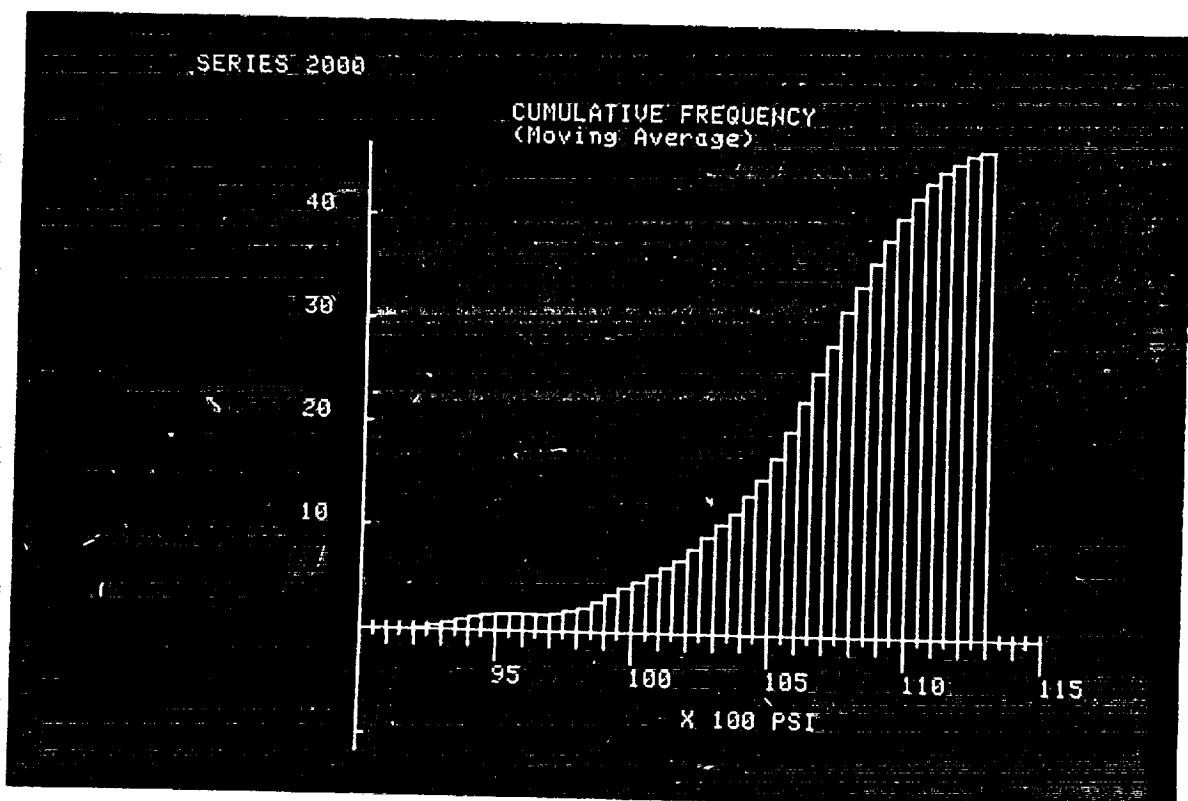
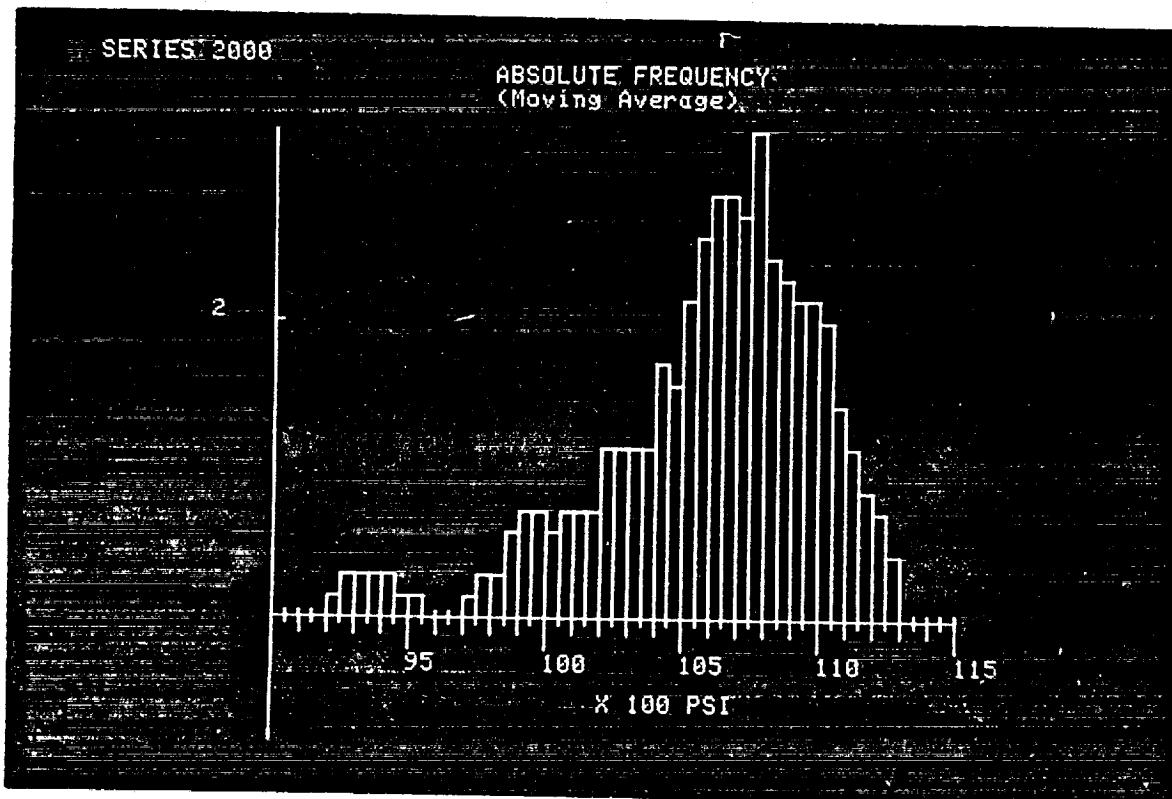
110 115 120 125 130 135 140 145 150 155 160  
X 100 PSI

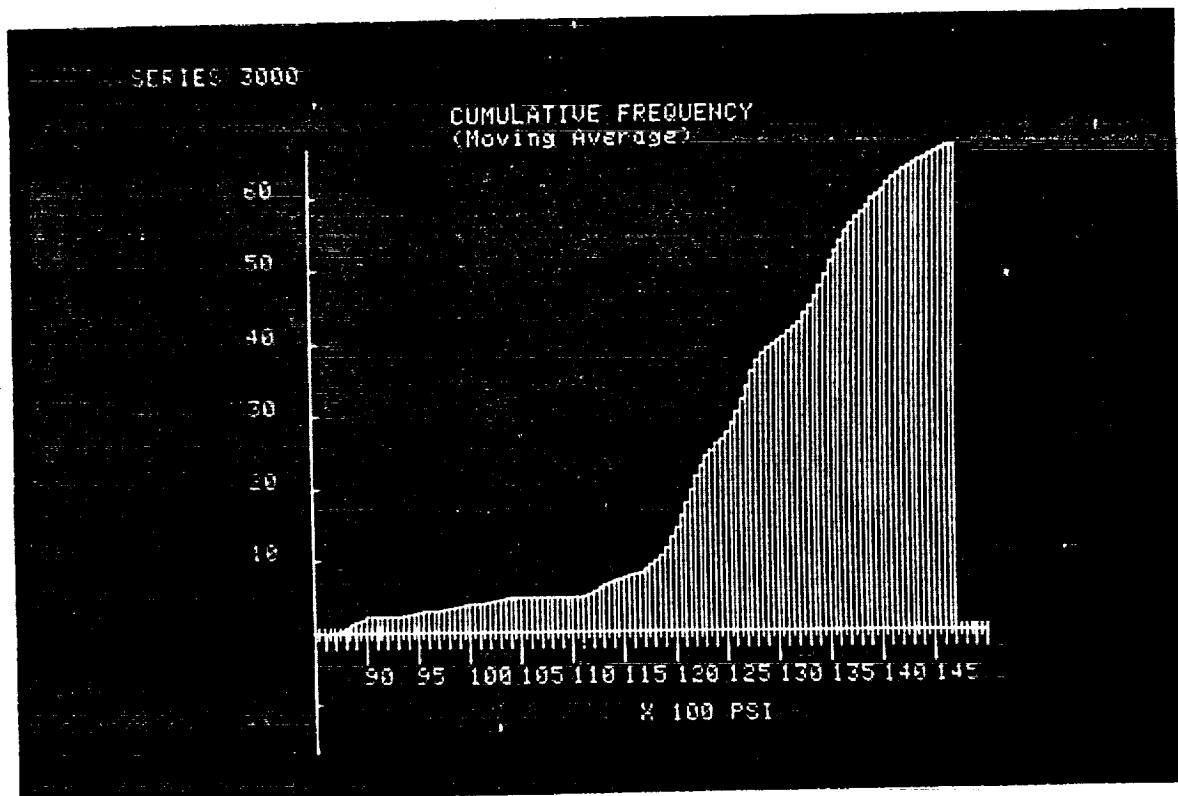
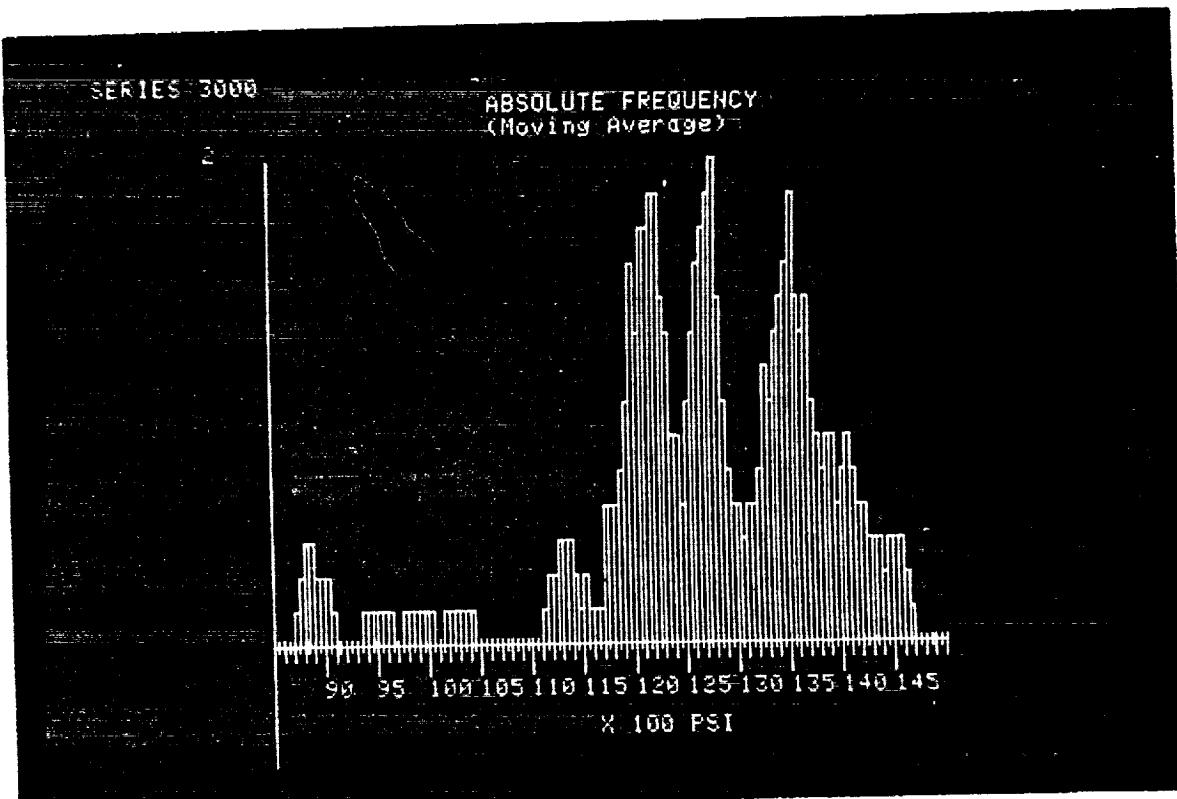
SERIES 1000

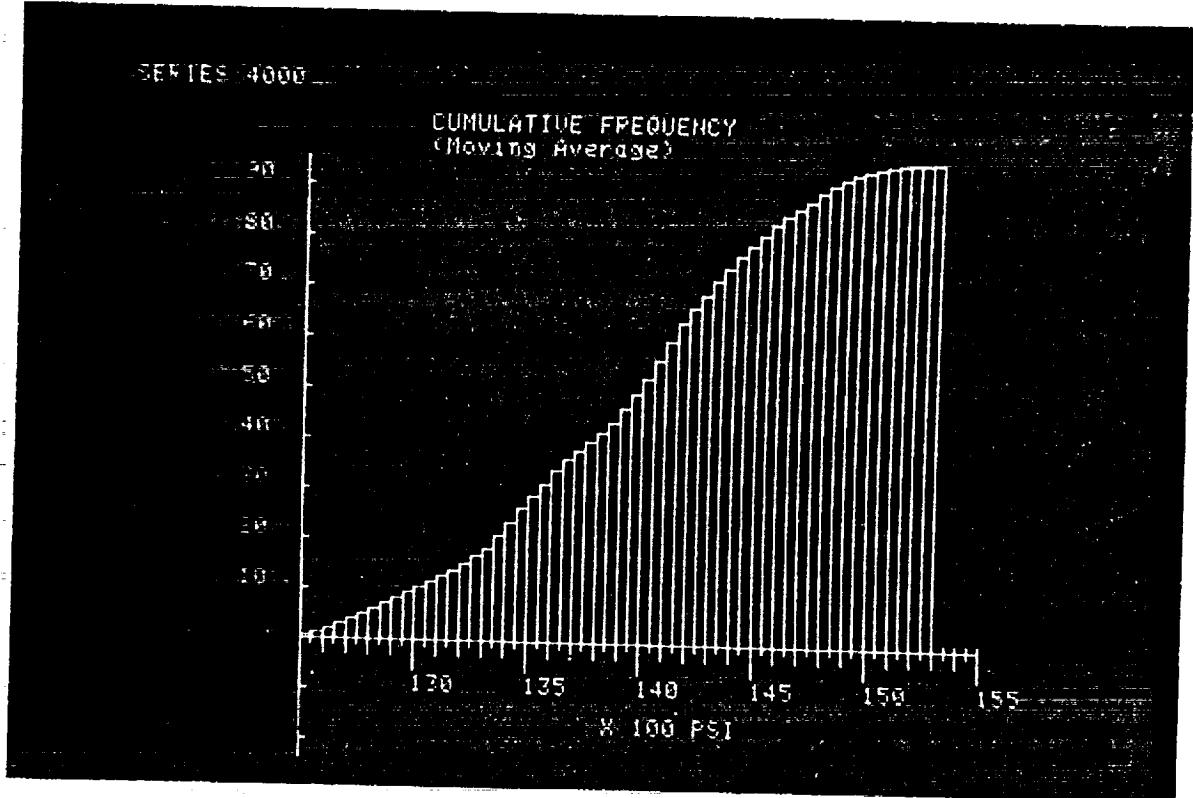
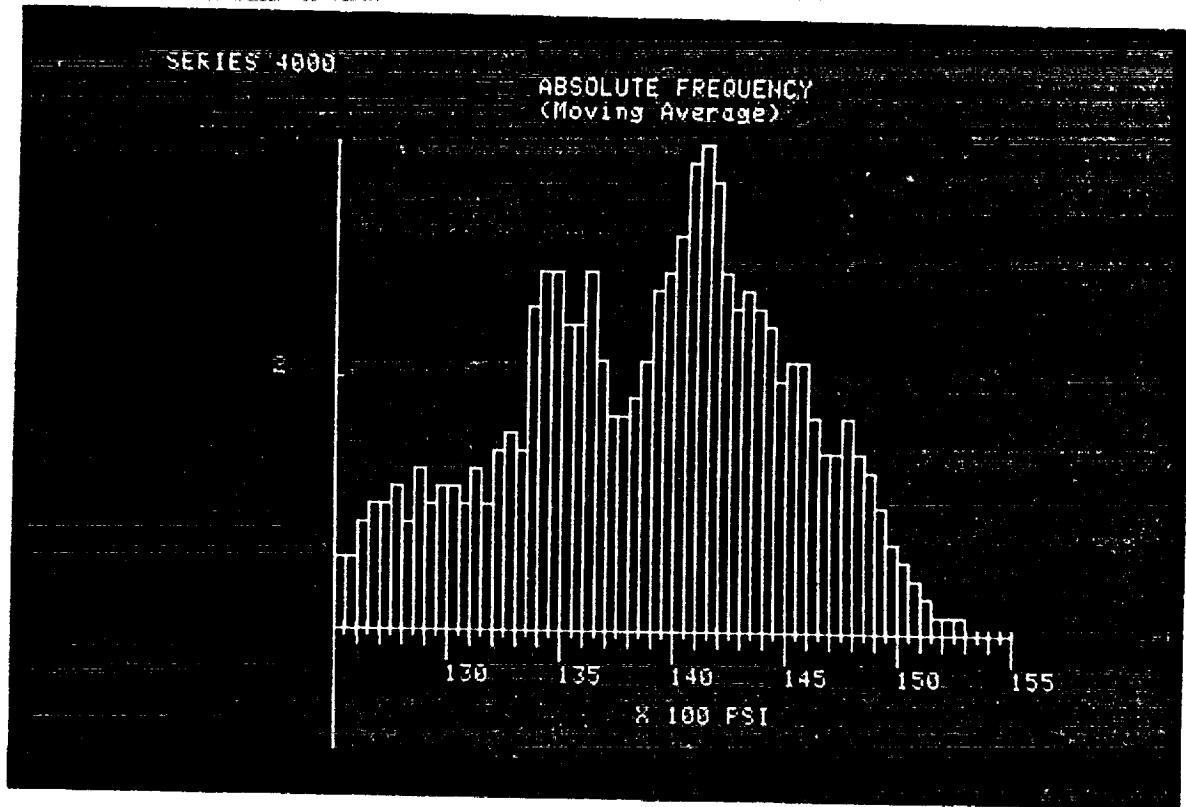
CUMULATIVE FREQUENCY  
(Moving Average)

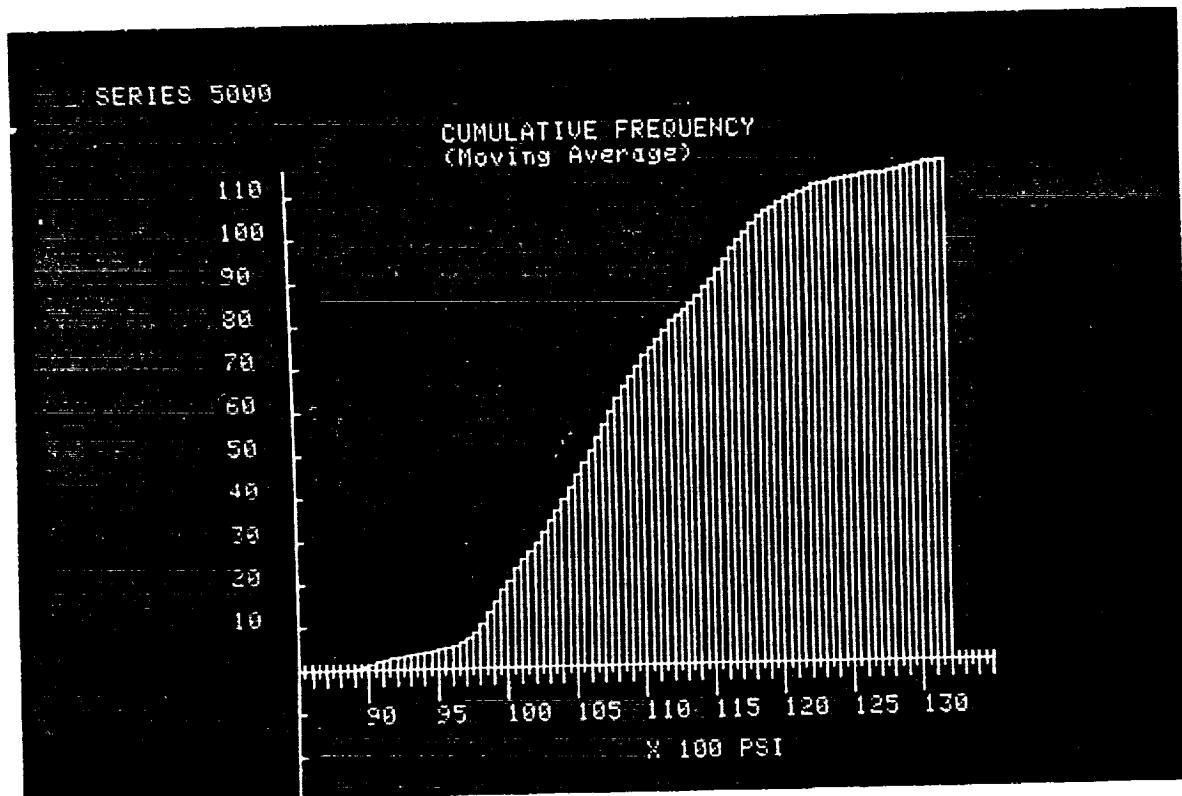
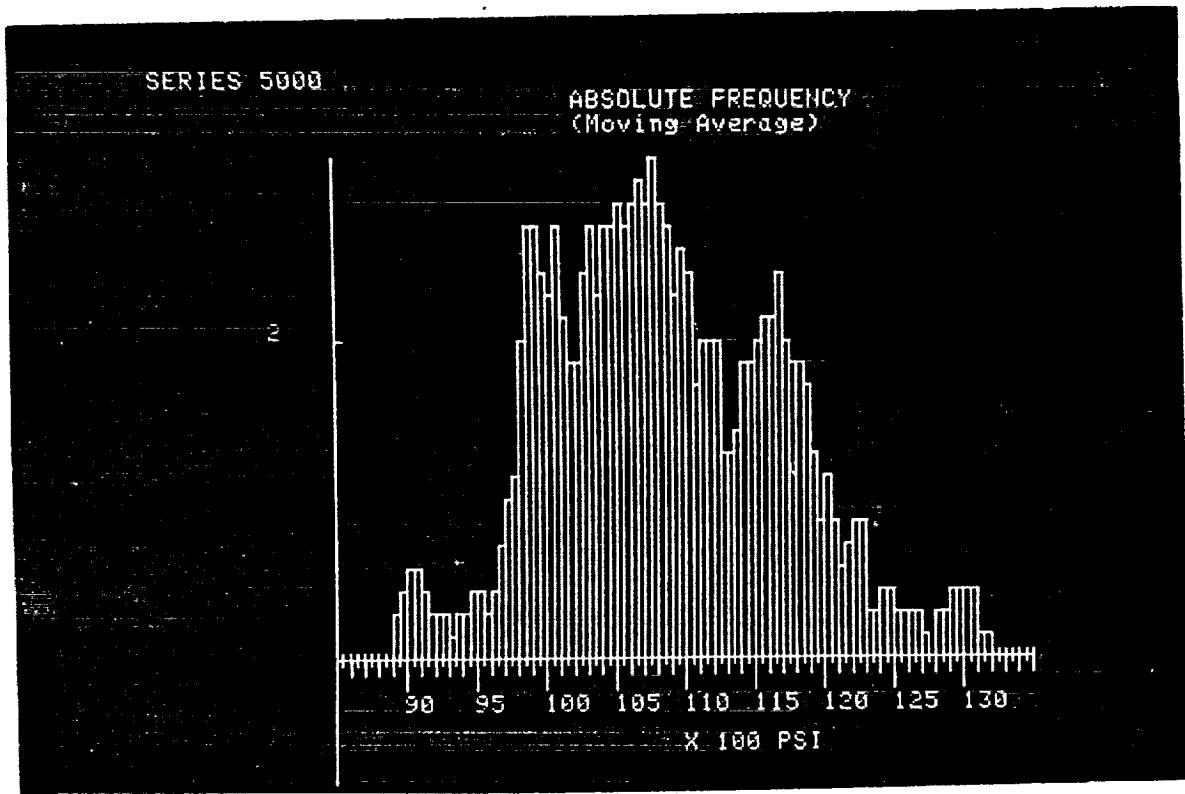
88  
78  
68  
58  
48  
38  
28  
18

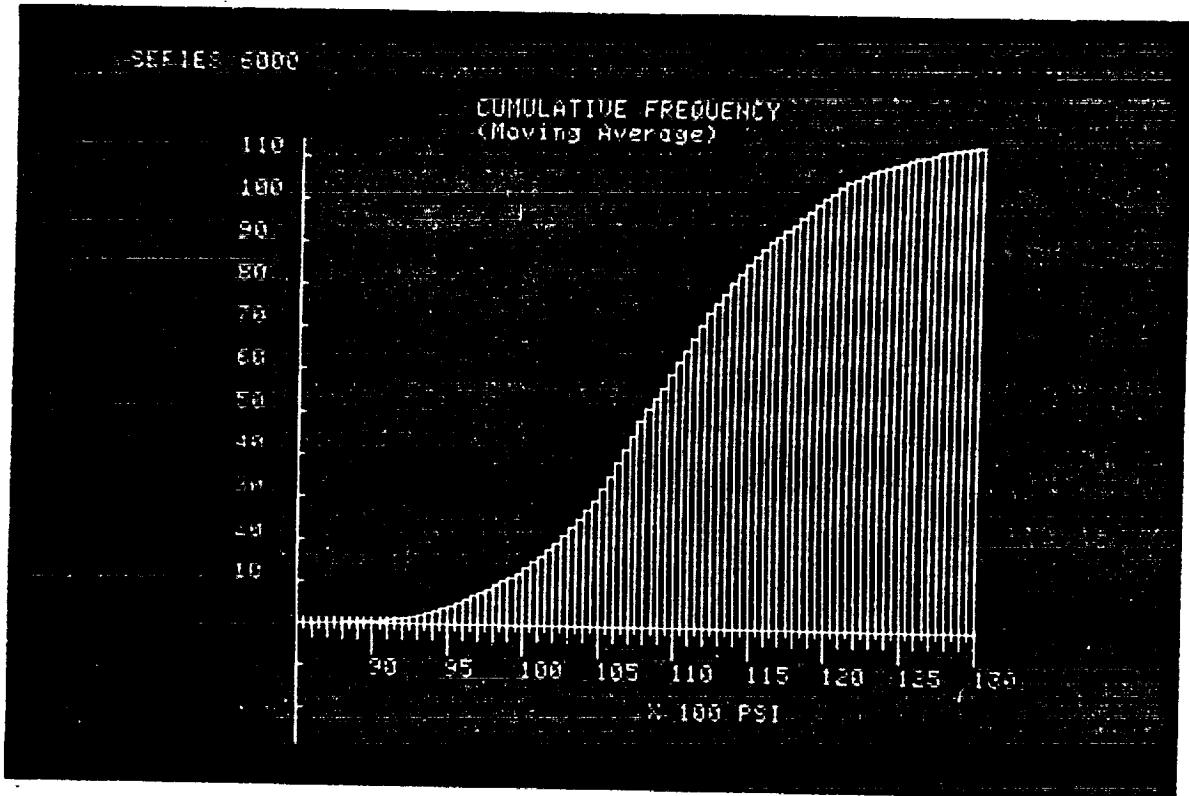
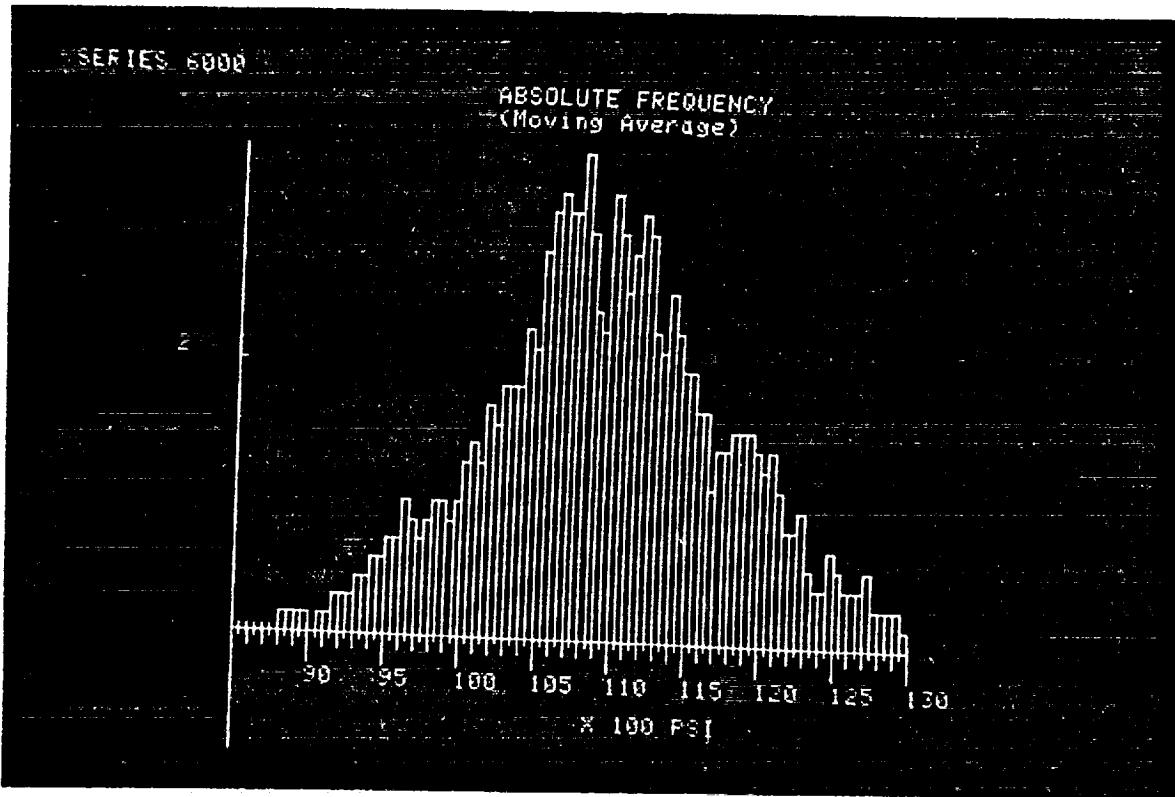
110 115 120 125 130 135 140 145 150 155 160  
X 100 PSI

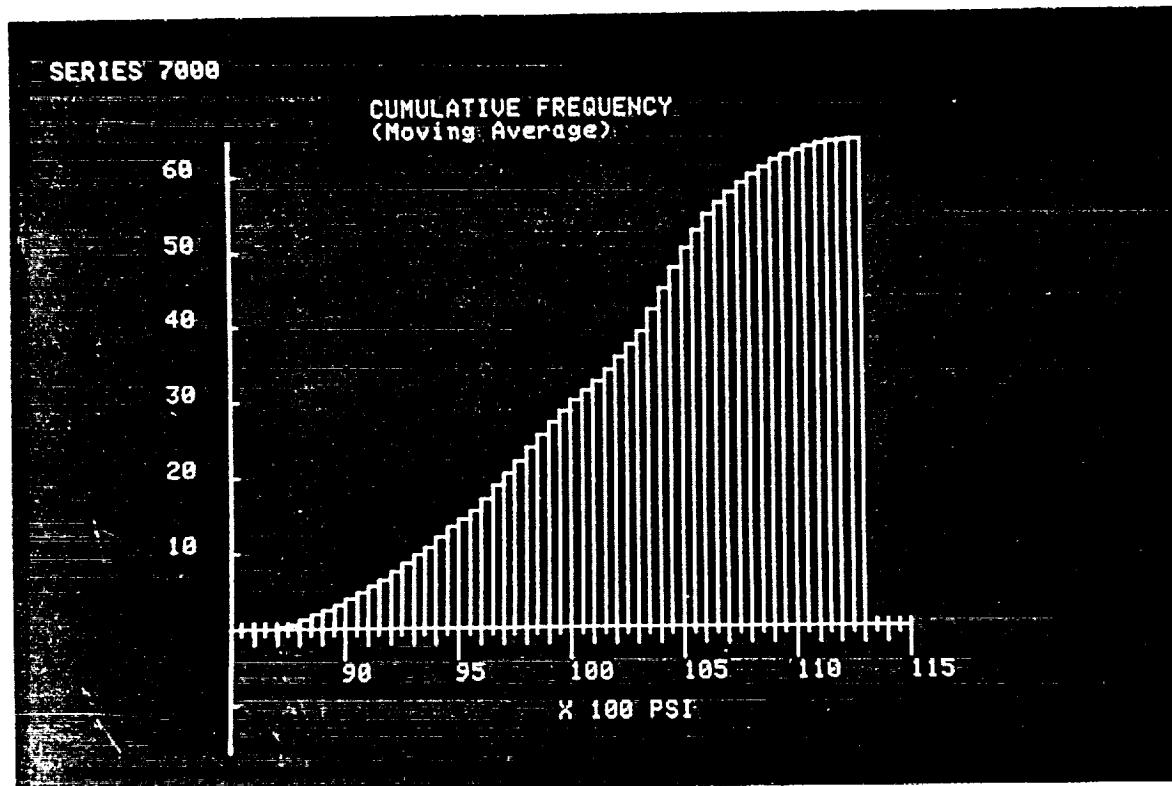
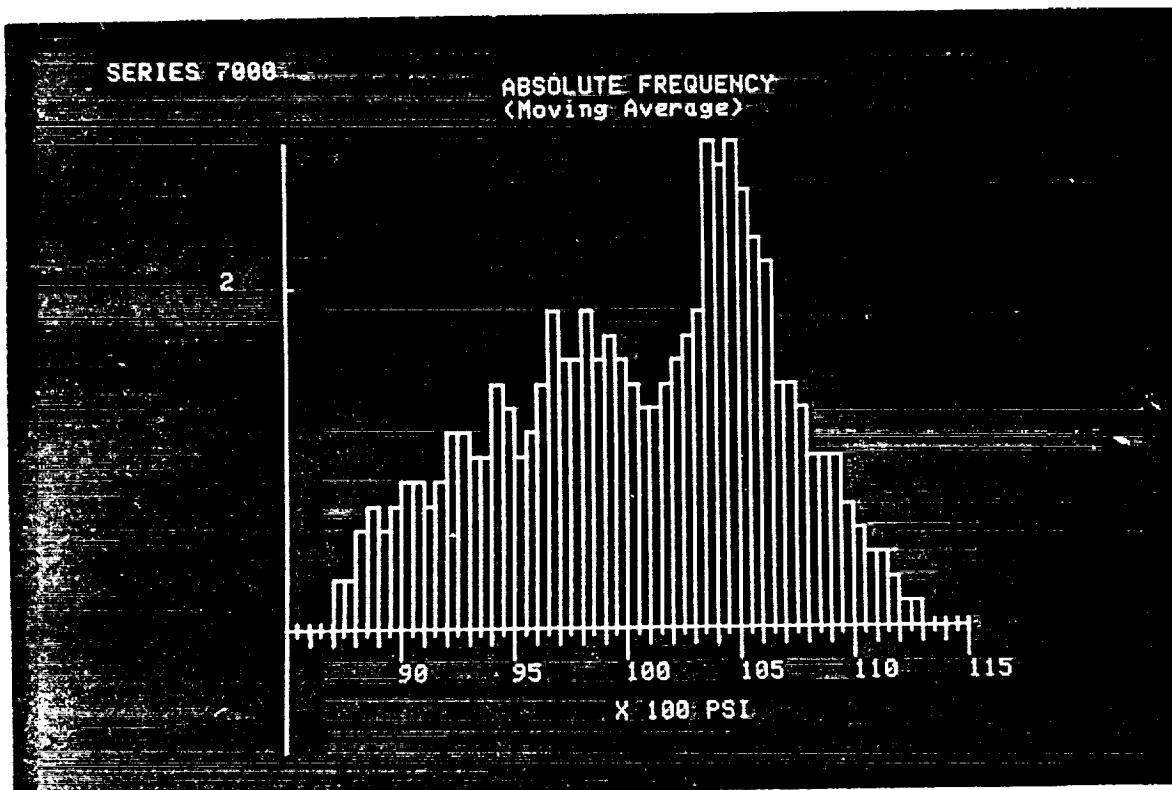


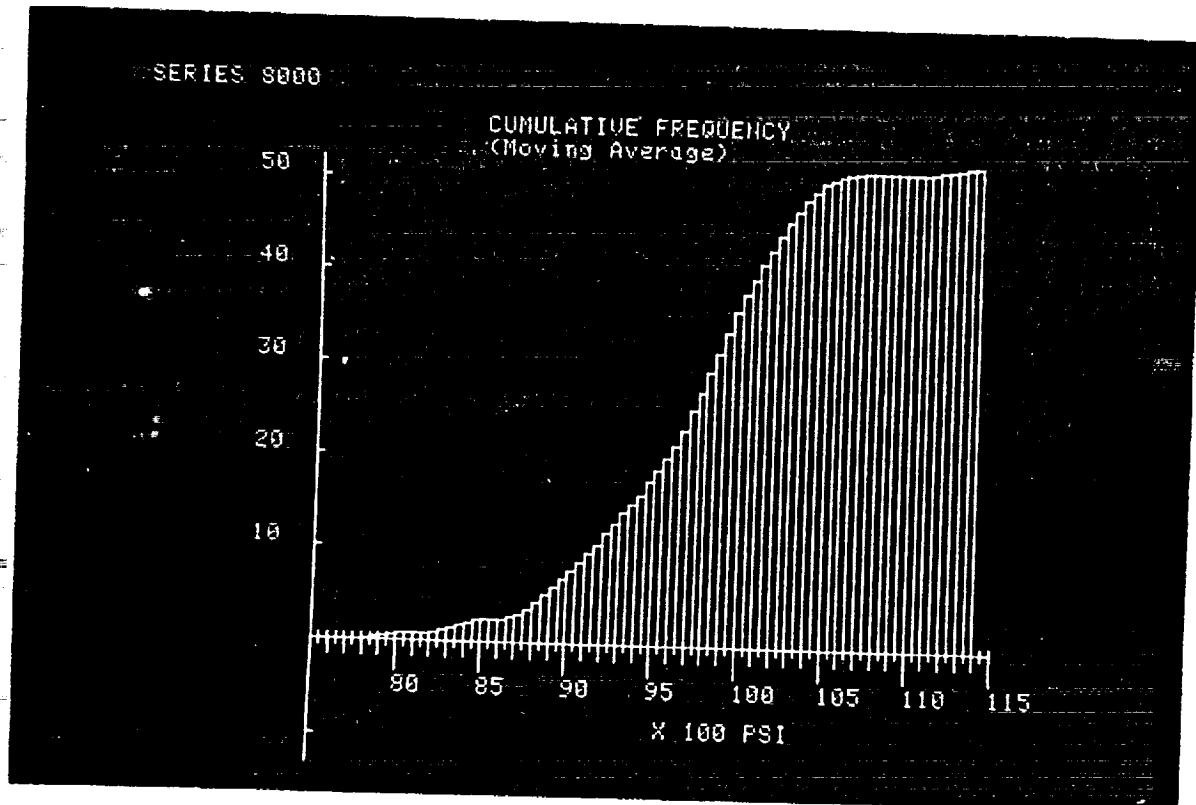
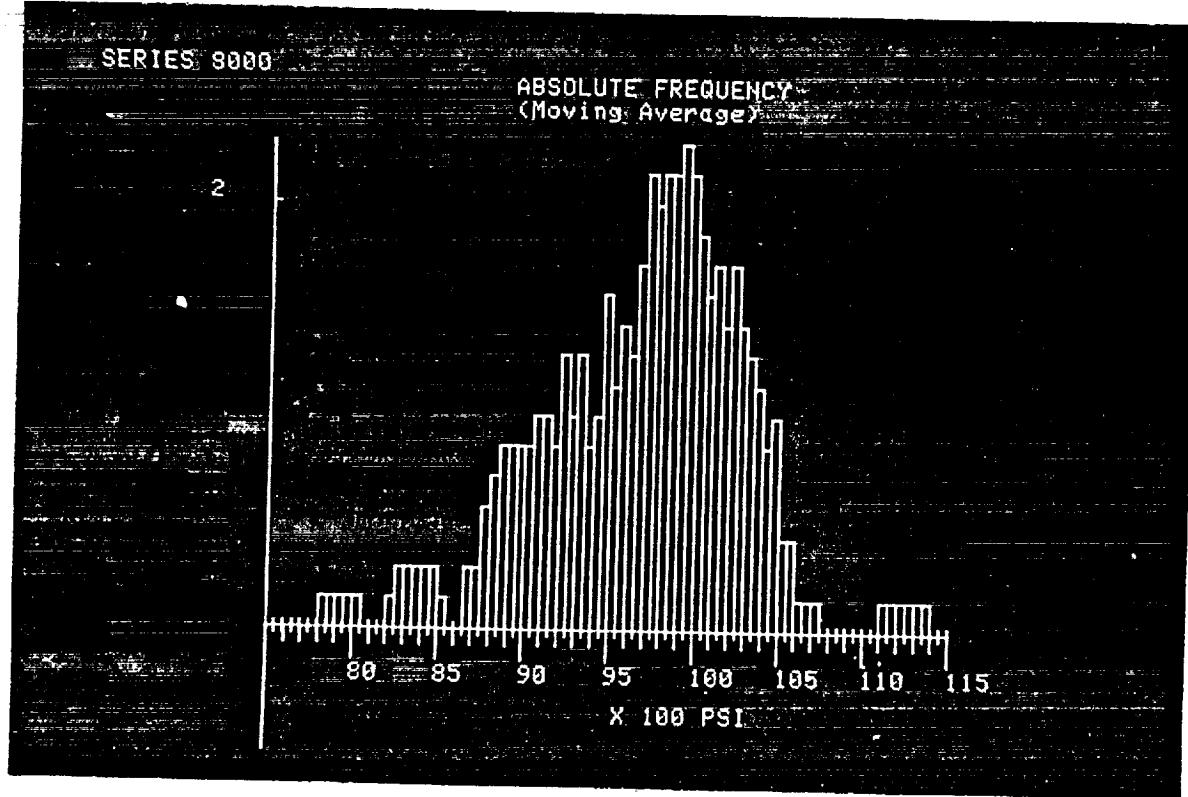


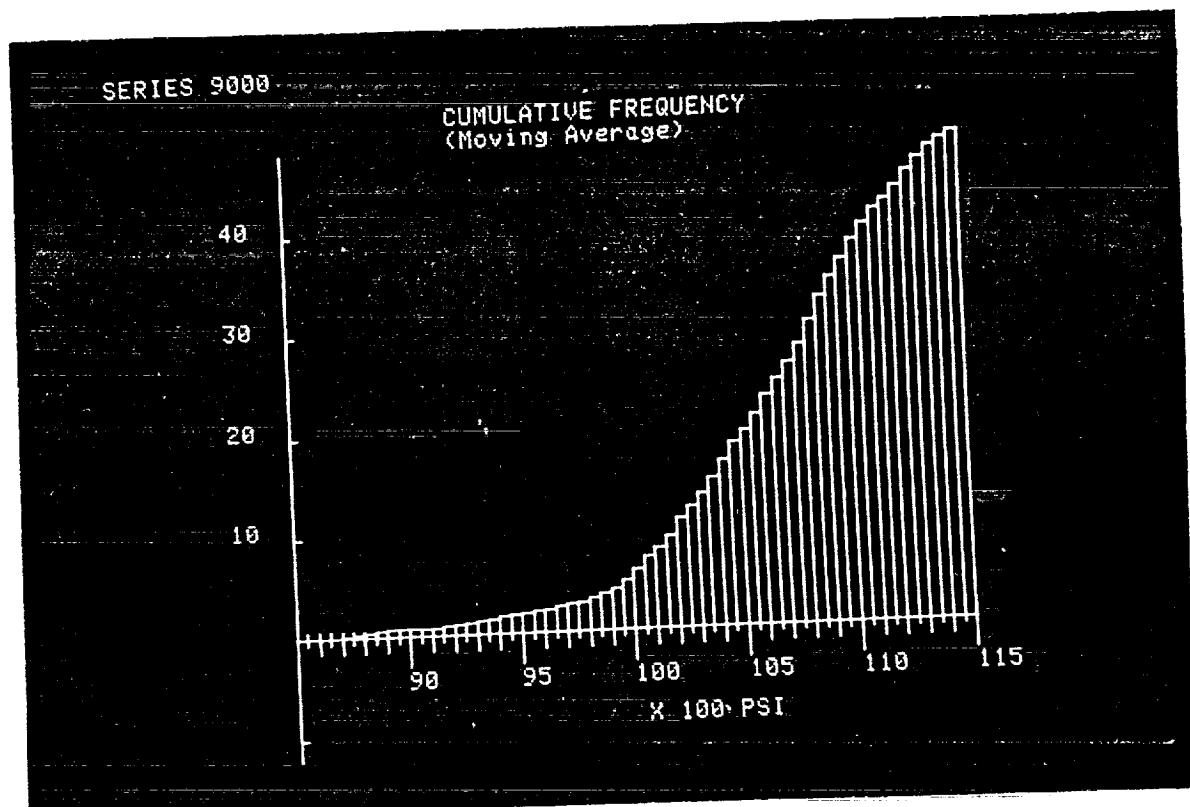
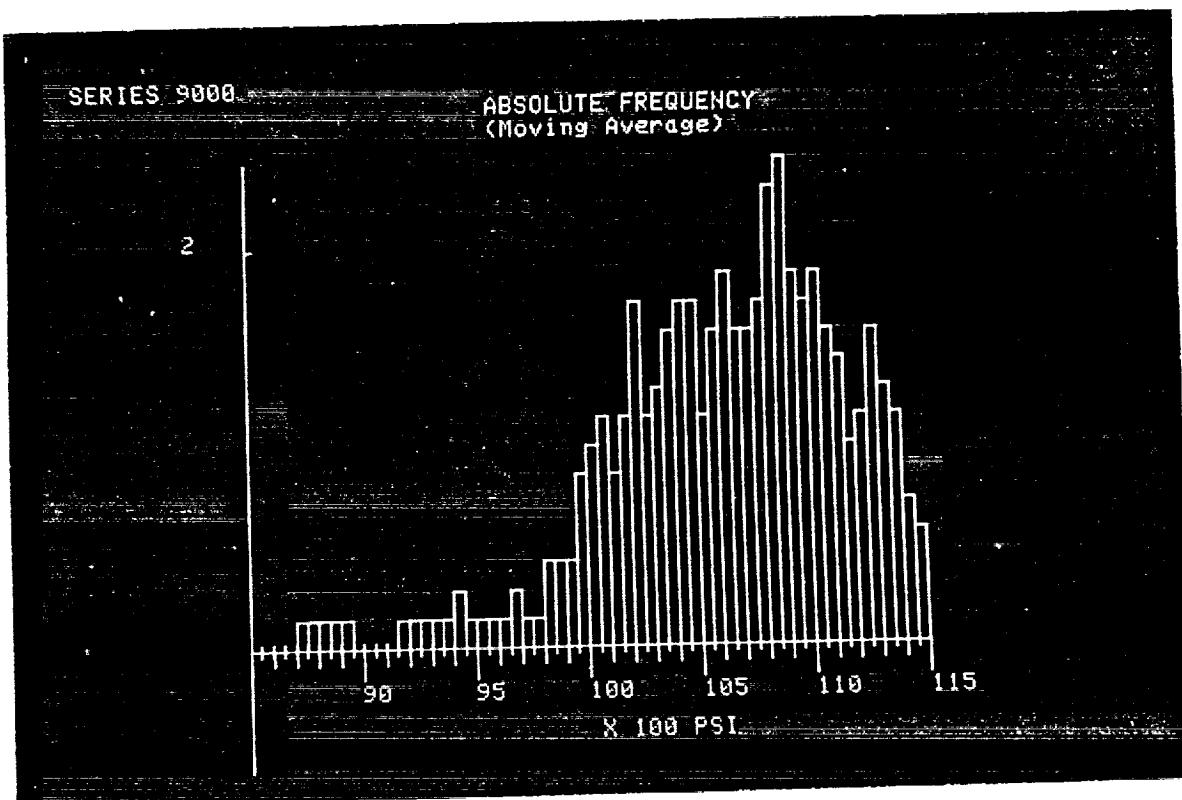


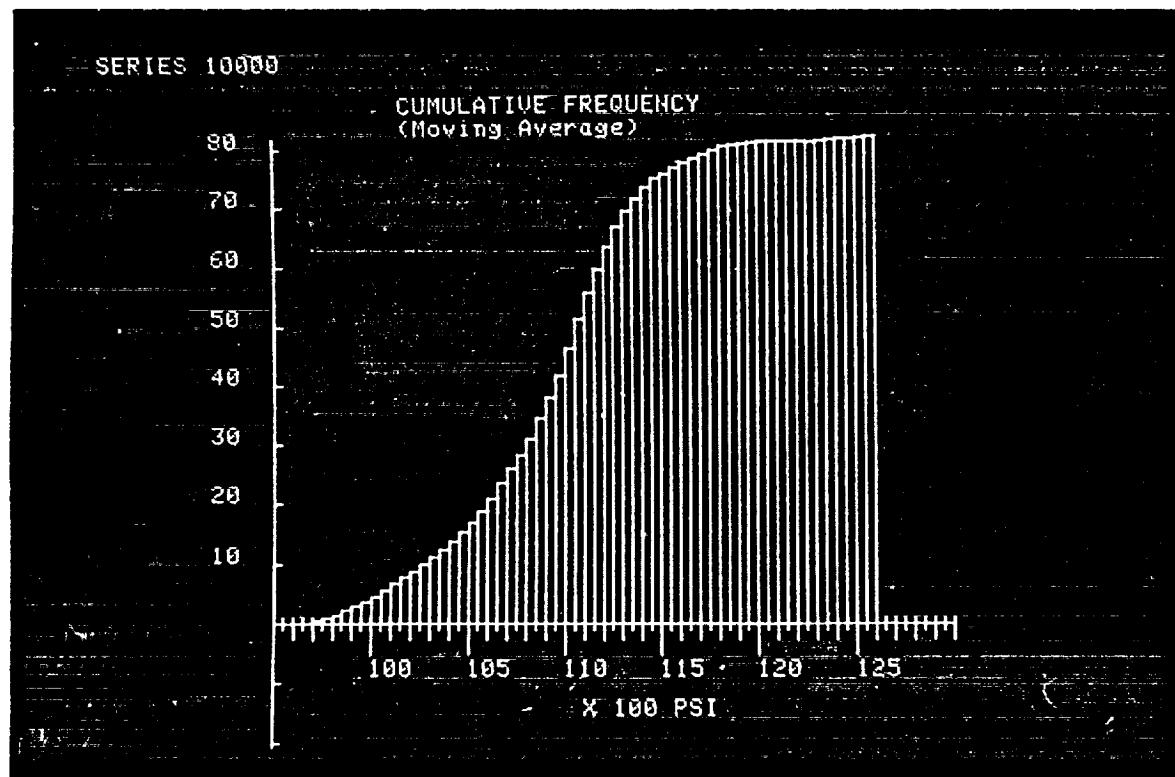
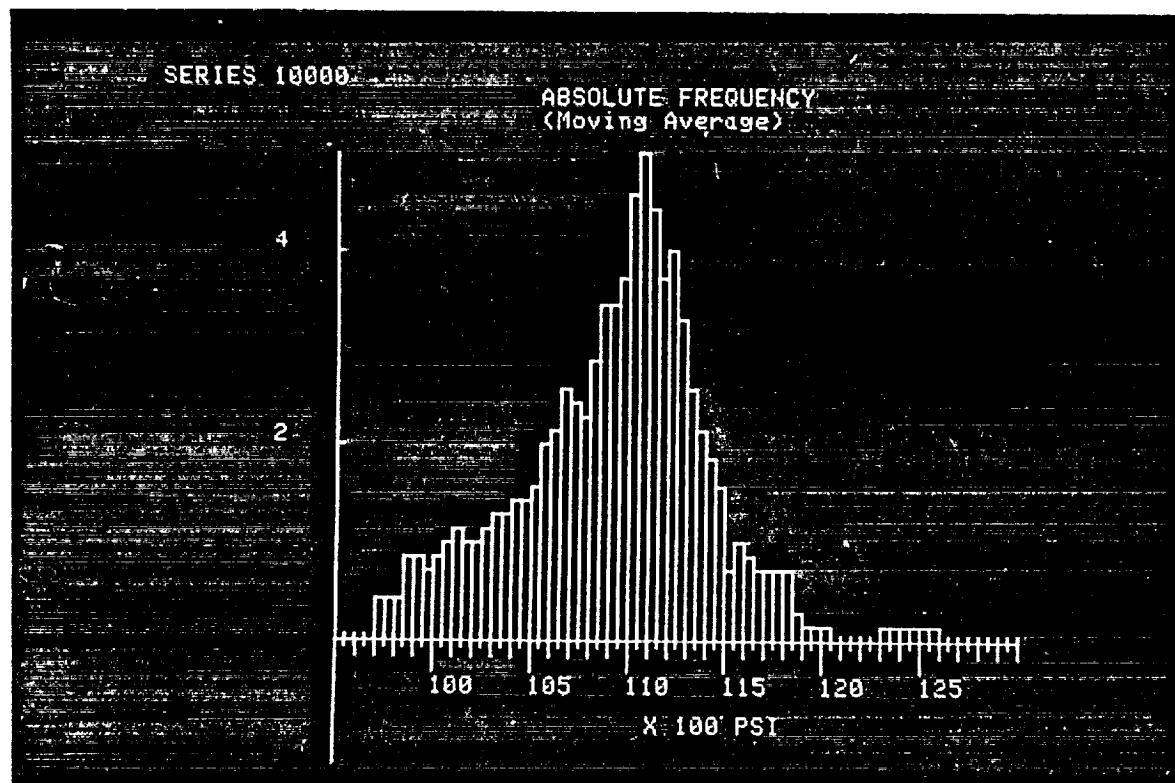


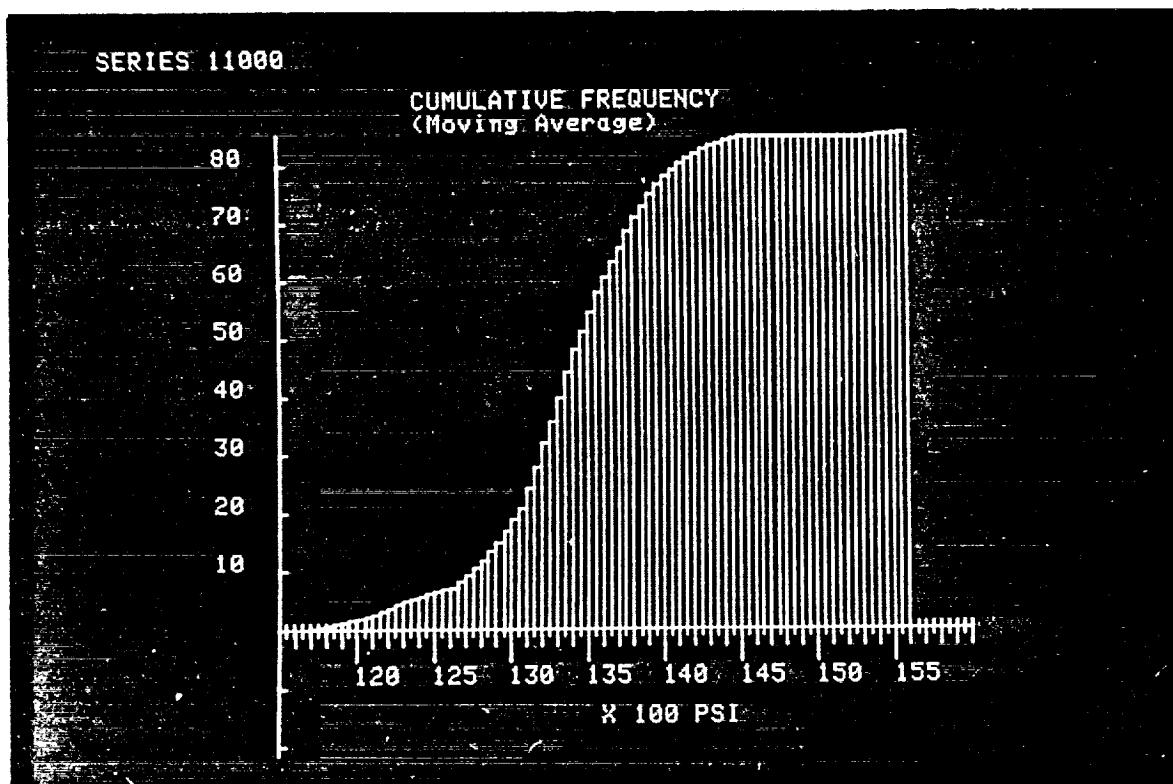
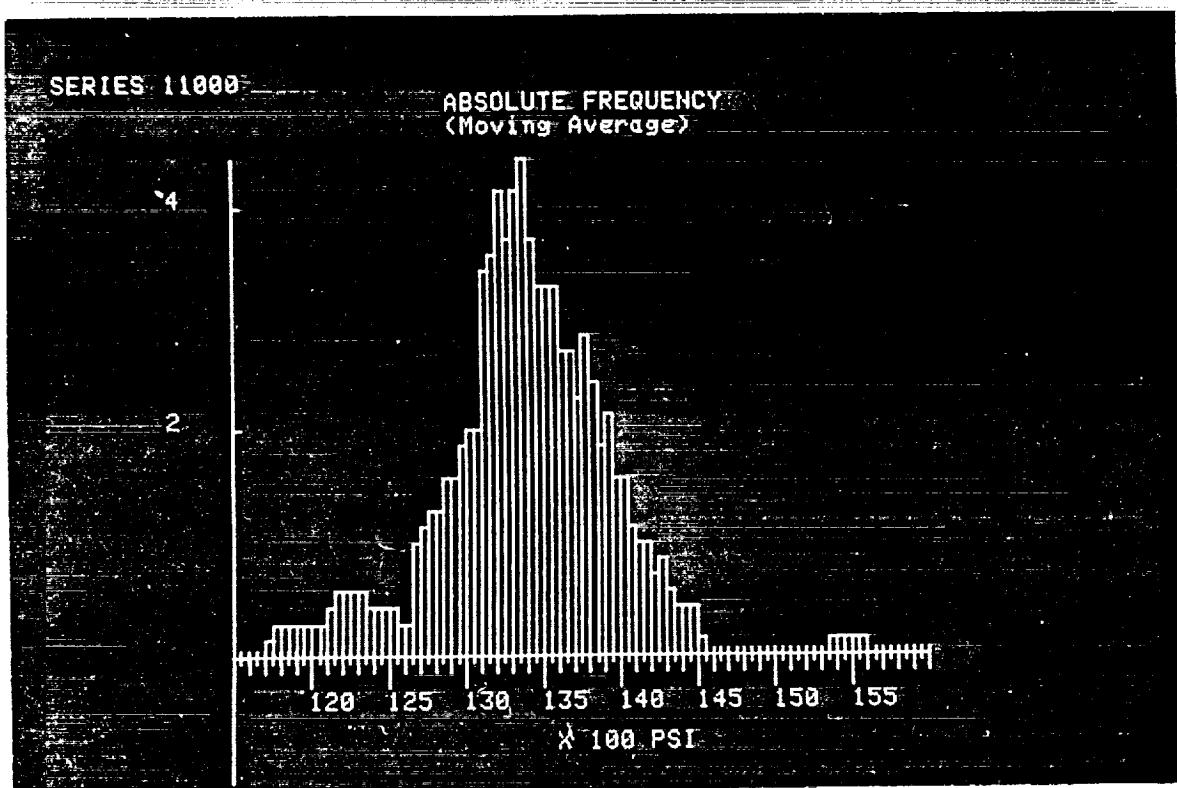












#### **SECTION IV.**

SERIES 1000 NORMAL

CUMULATIVE FREQUENCY

80  
70  
60  
50  
40  
30  
20  
10

105 110 115 120 125 130 135 140 145 150 155 160

x 100 PSI

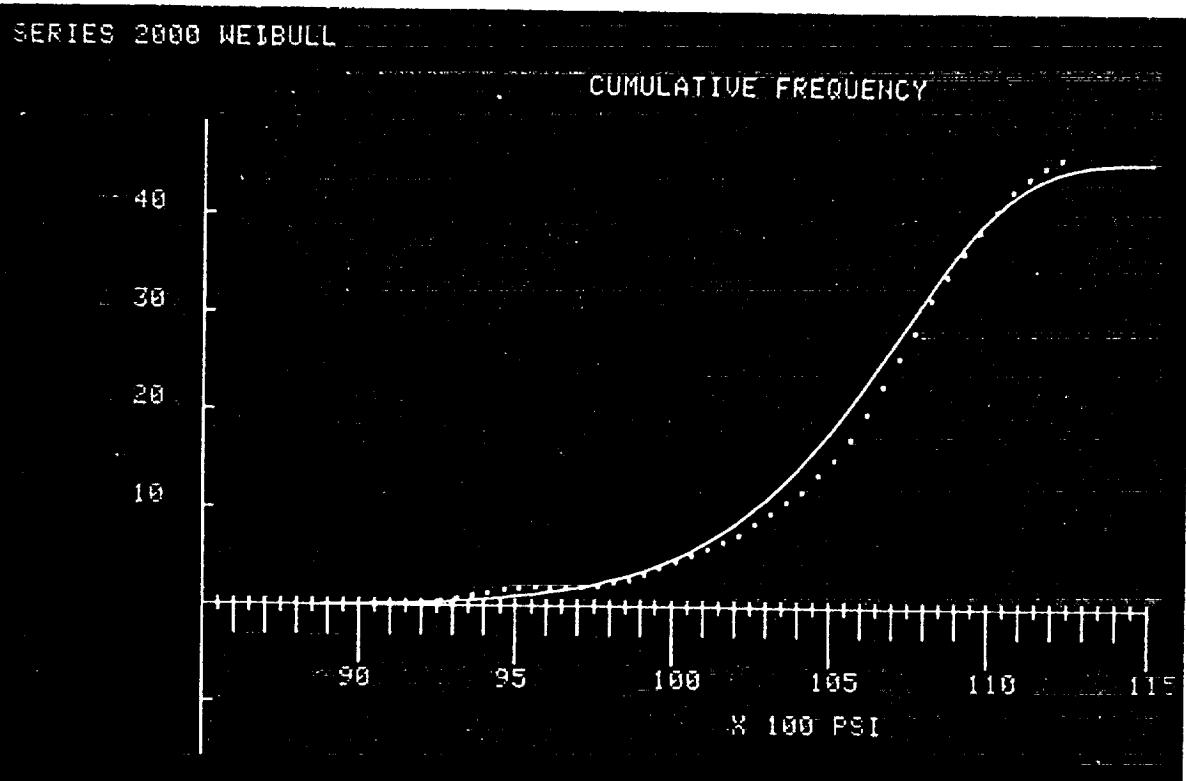
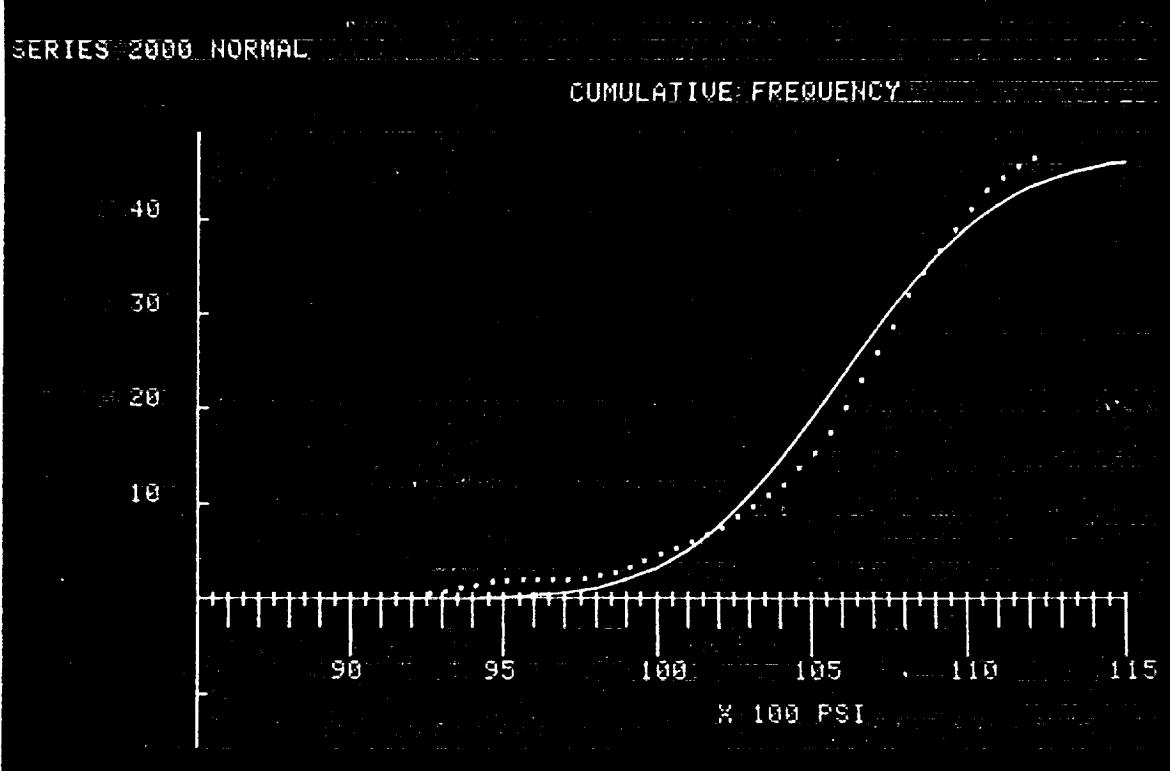
SERIES 1000 WEIBULL

CUMULATIVE FREQUENCY

80  
70  
60  
50  
40  
30  
20  
10

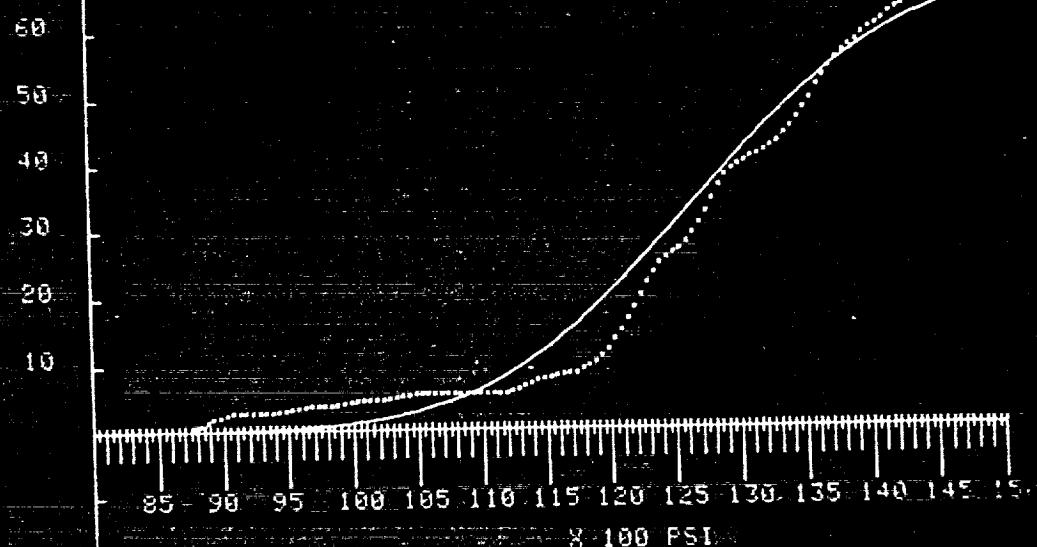
105 110 115 120 125 130 135 140 145 150 155 160

x 100 PSI



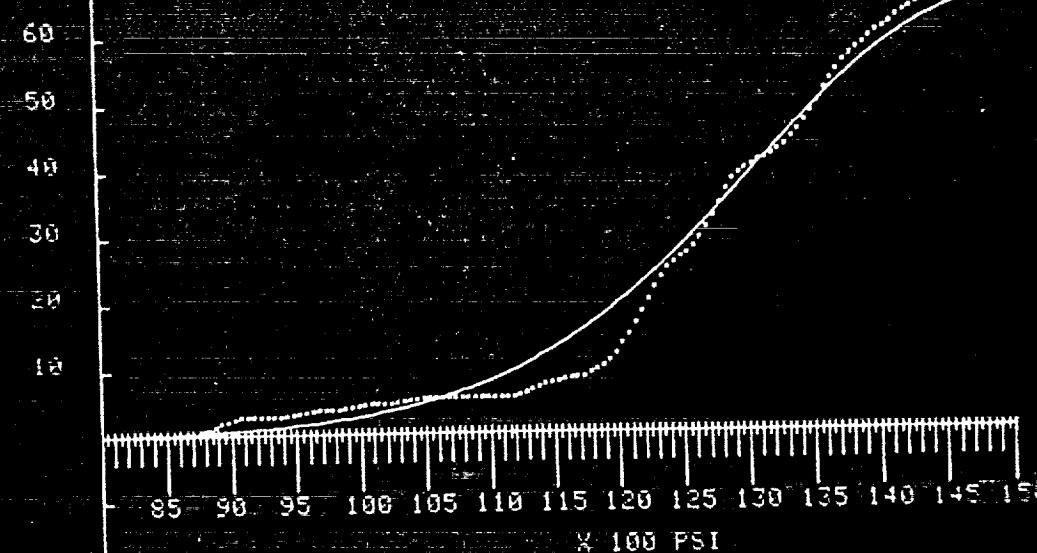
SERIES 3000 NORMAL

CUMULATIVE FREQUENCY



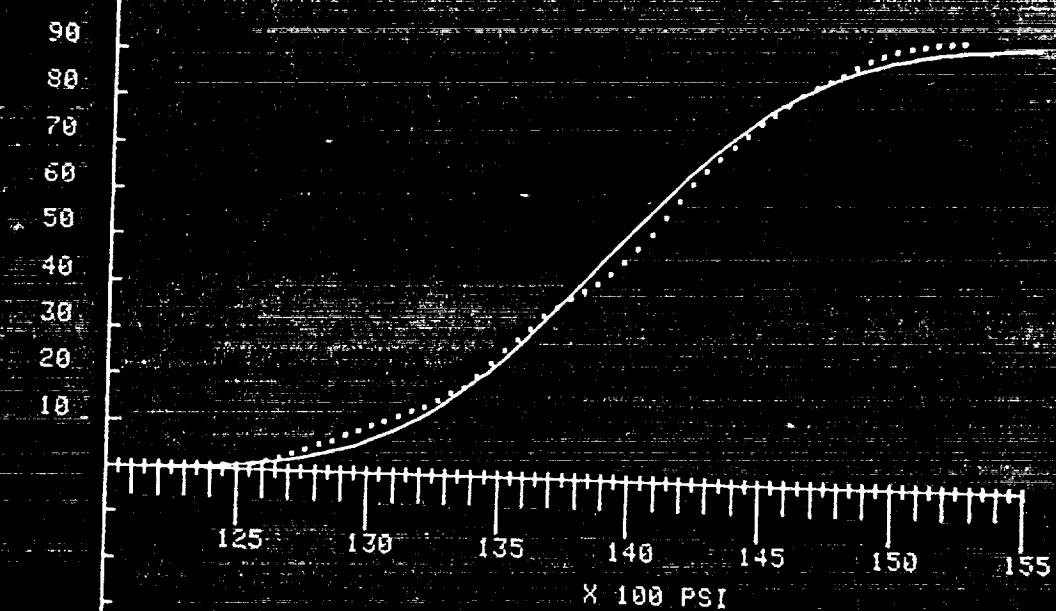
SERIES 3000 WEIBUL

CUMULATIVE FREQUENCY



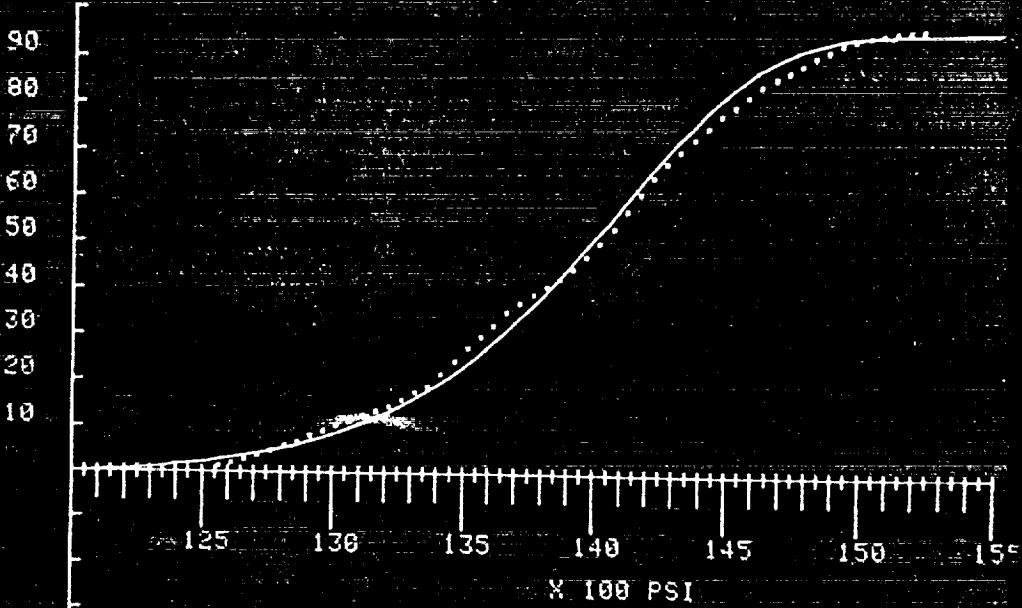
SERIES 4000 NORMAL

CUMULATIVE FREQUENCY



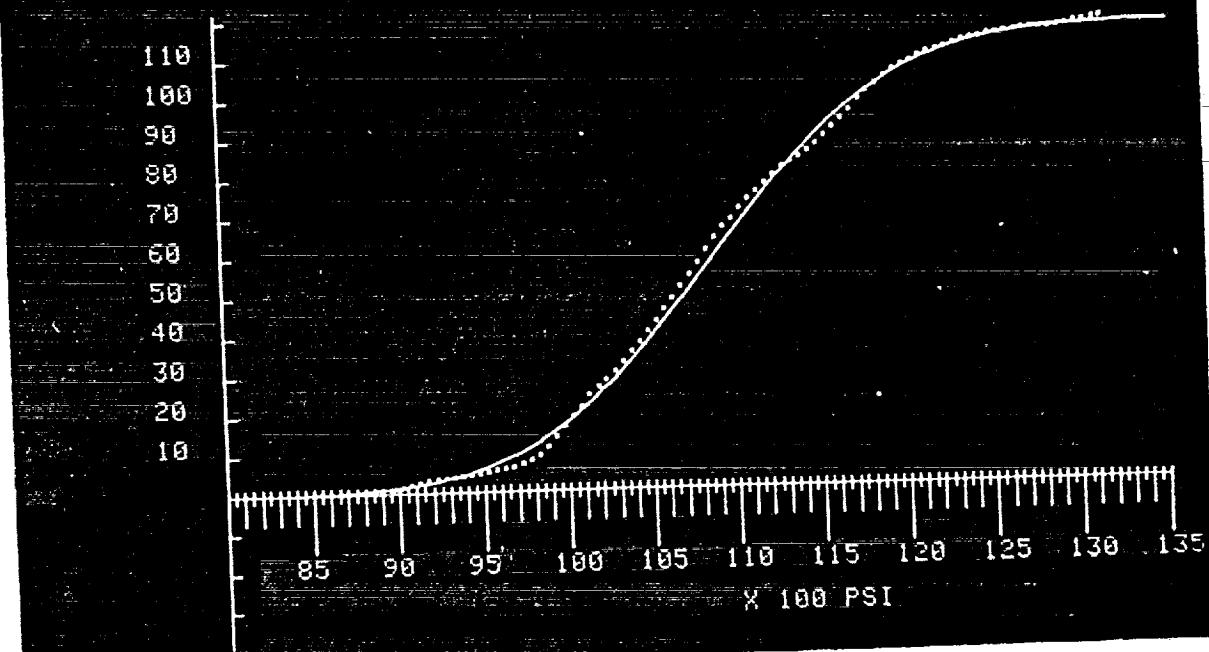
SERIES 4000 WEIBUL

CUMULATIVE FREQUENCY



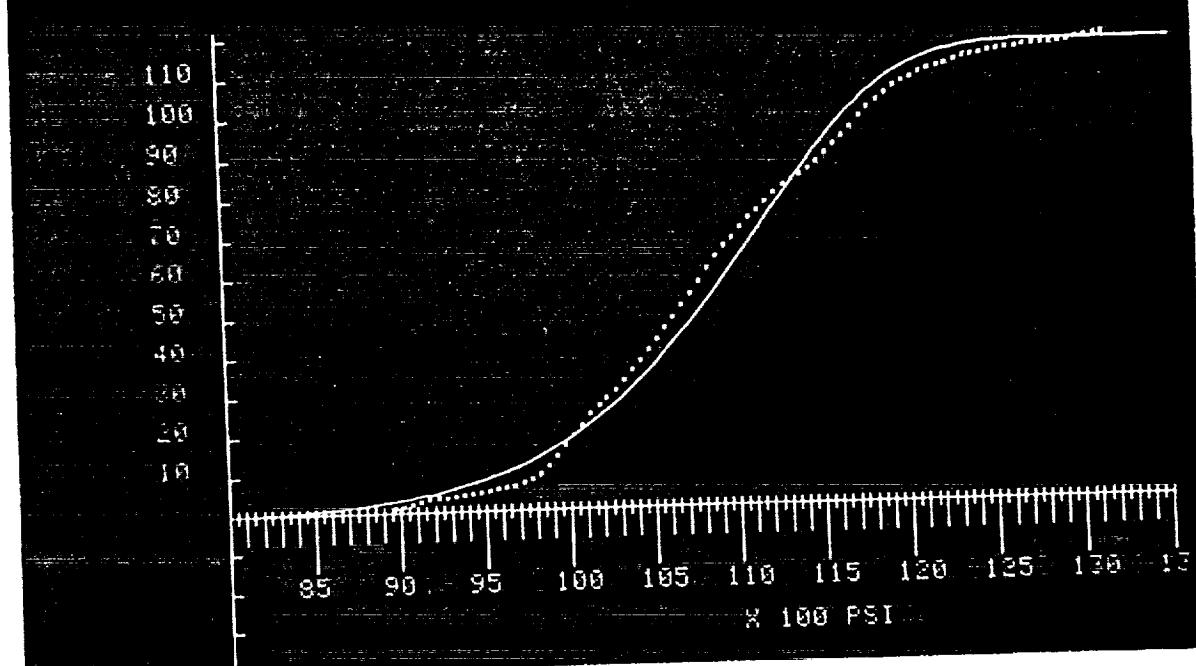
SERIES 5000 NORMAL

CUMULATIVE FREQUENCY



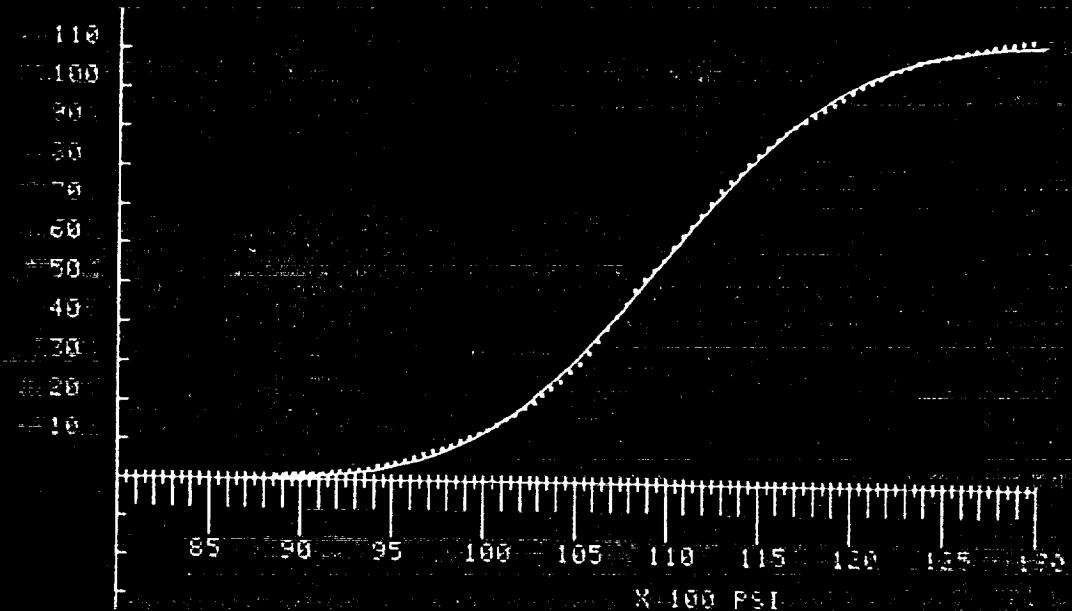
SERIES 5000 WEIBUL

CUMULATIVE FREQUENCY



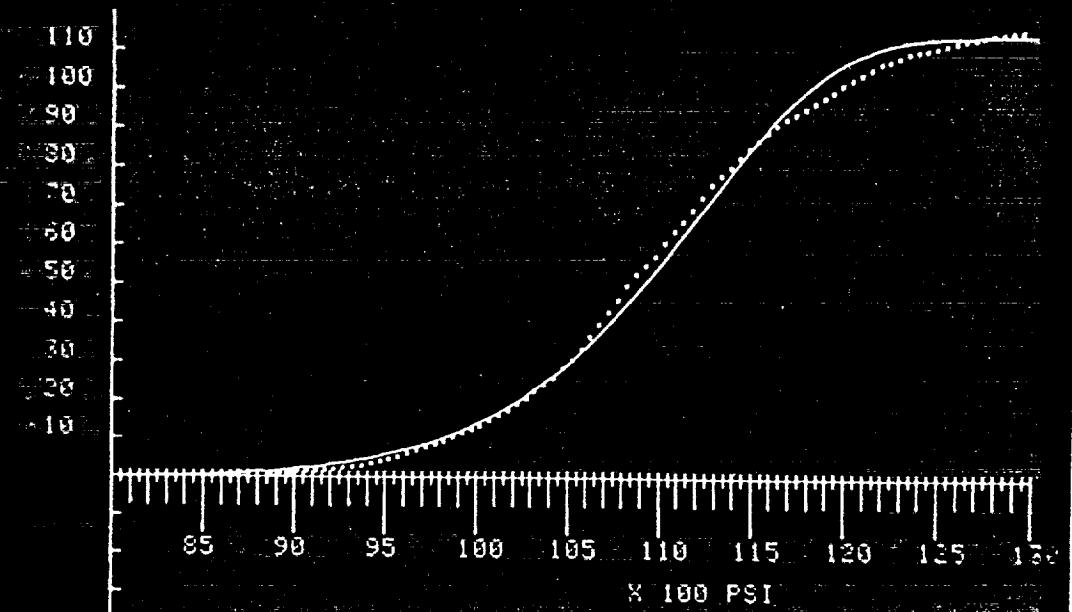
SERIES 6000 NORMAL

CUMULATIVE FREQUENCY



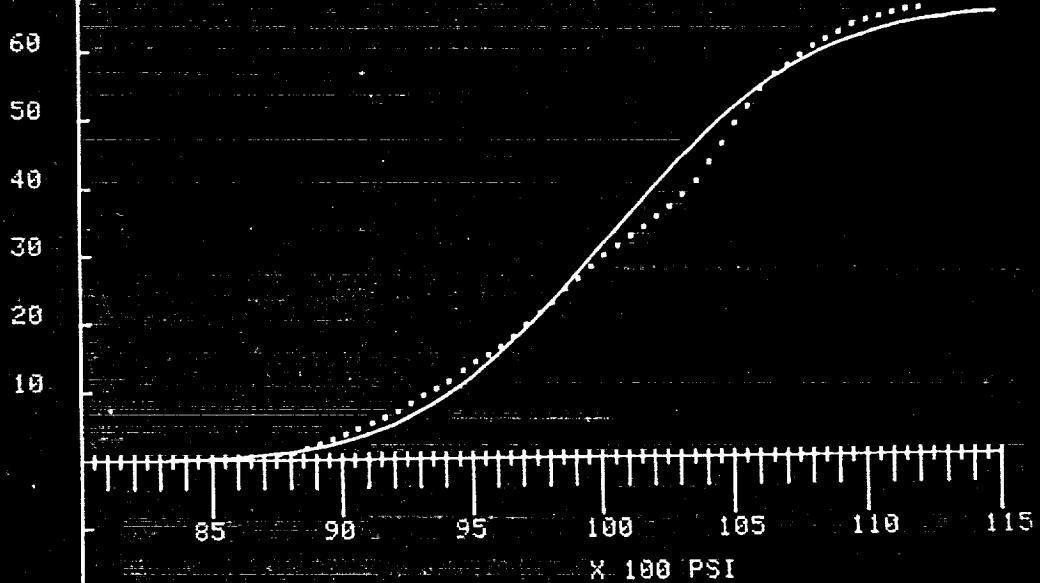
SERIES 6000 WEIBUL

CUMULATIVE FREQUENCY



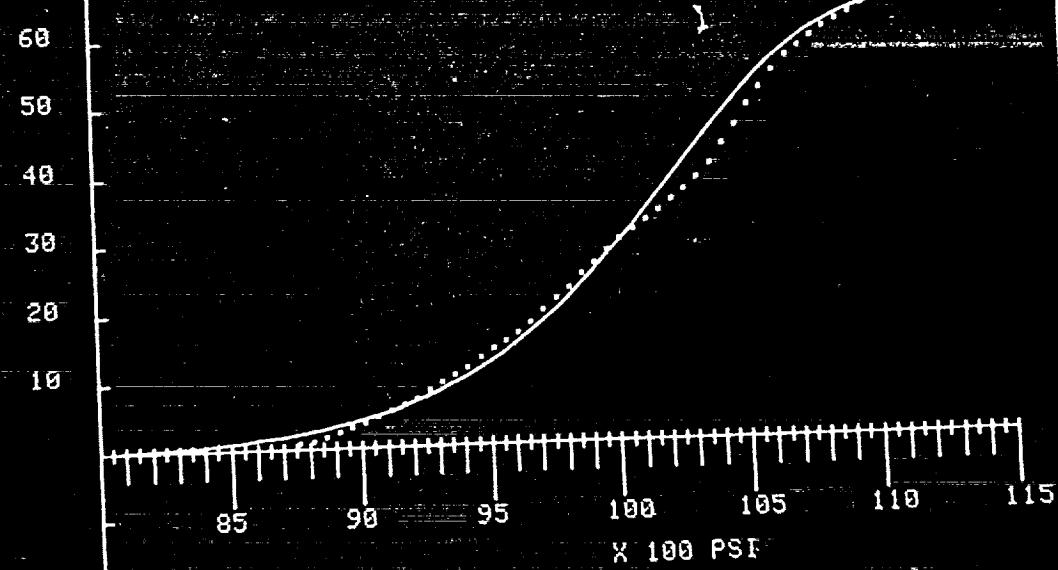
SERIES 7000 NORMAL

CUMULATIVE FREQUENCY



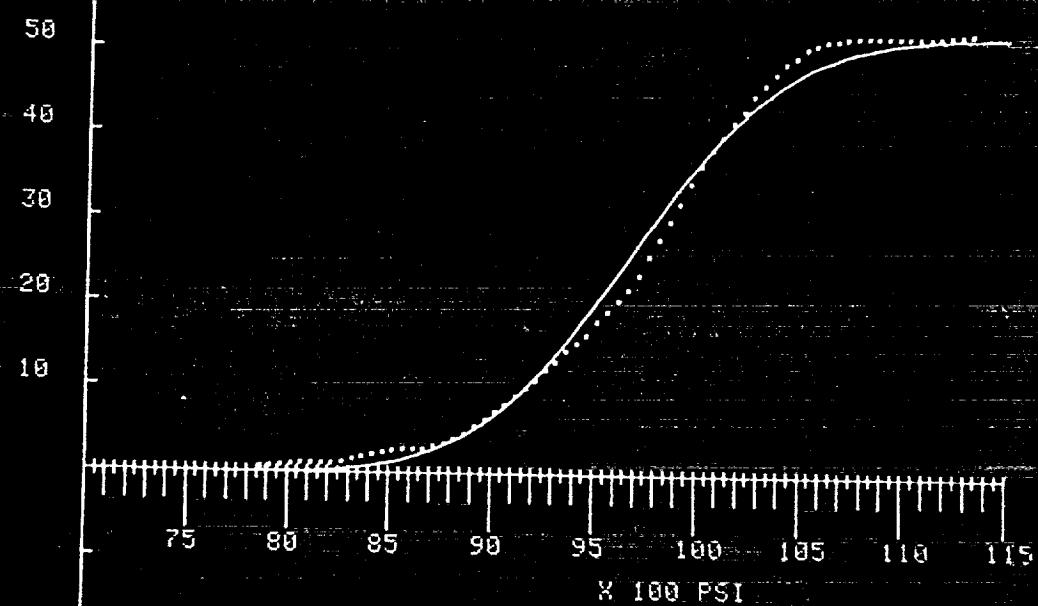
SERIES 7000 WEIBULL

CUMULATIVE FREQUENCY



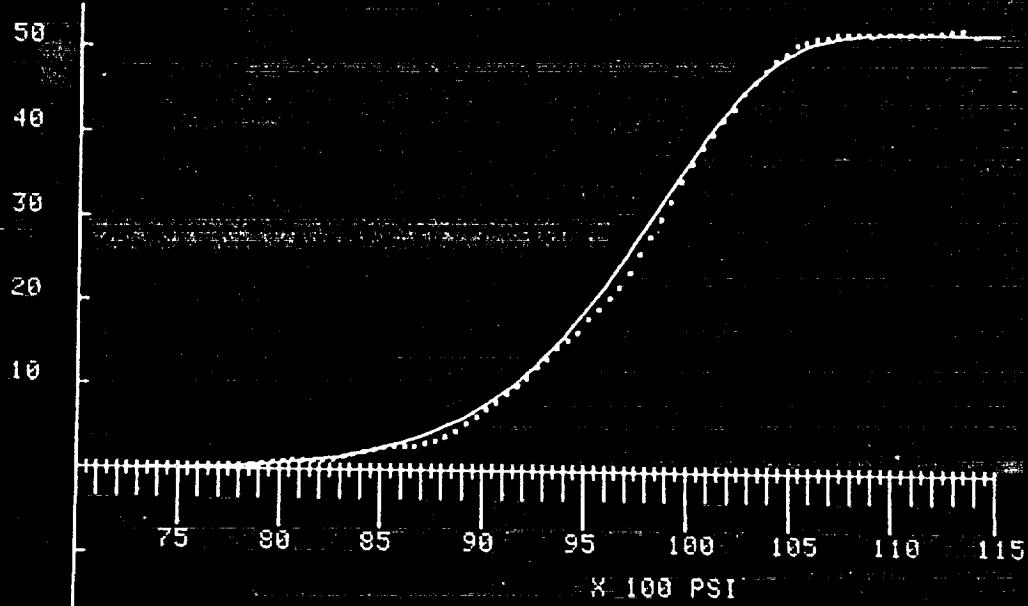
SERIES 8000 NORMAL

CUMULATIVE FREQUENCY



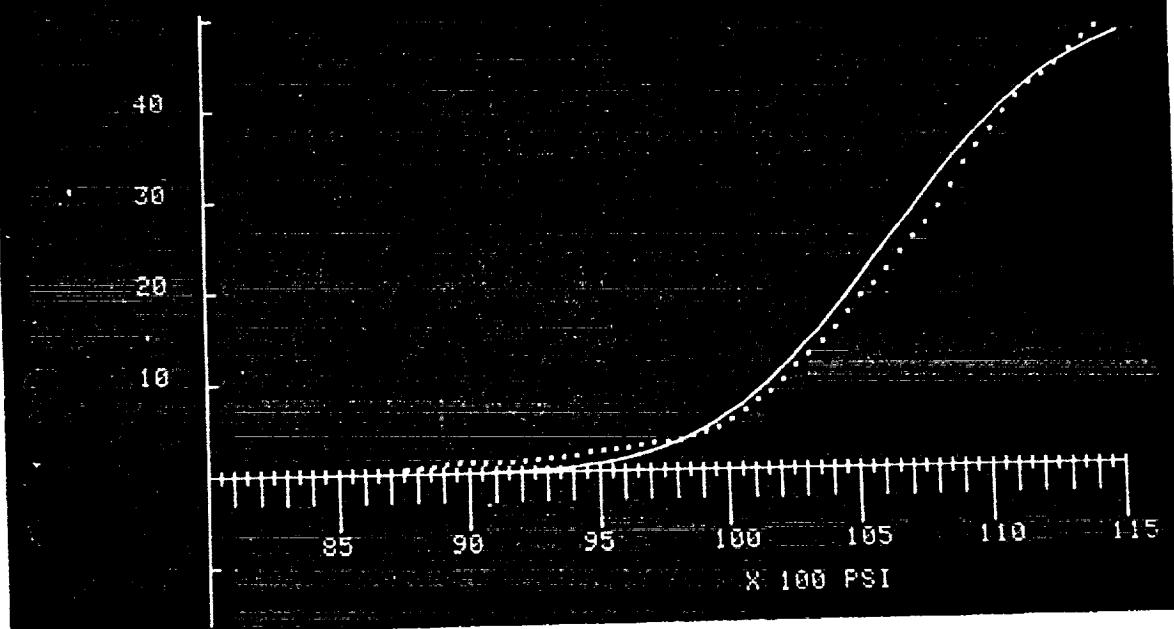
SERIES 8000 WEIBULL

CUMULATIVE FREQUENCY



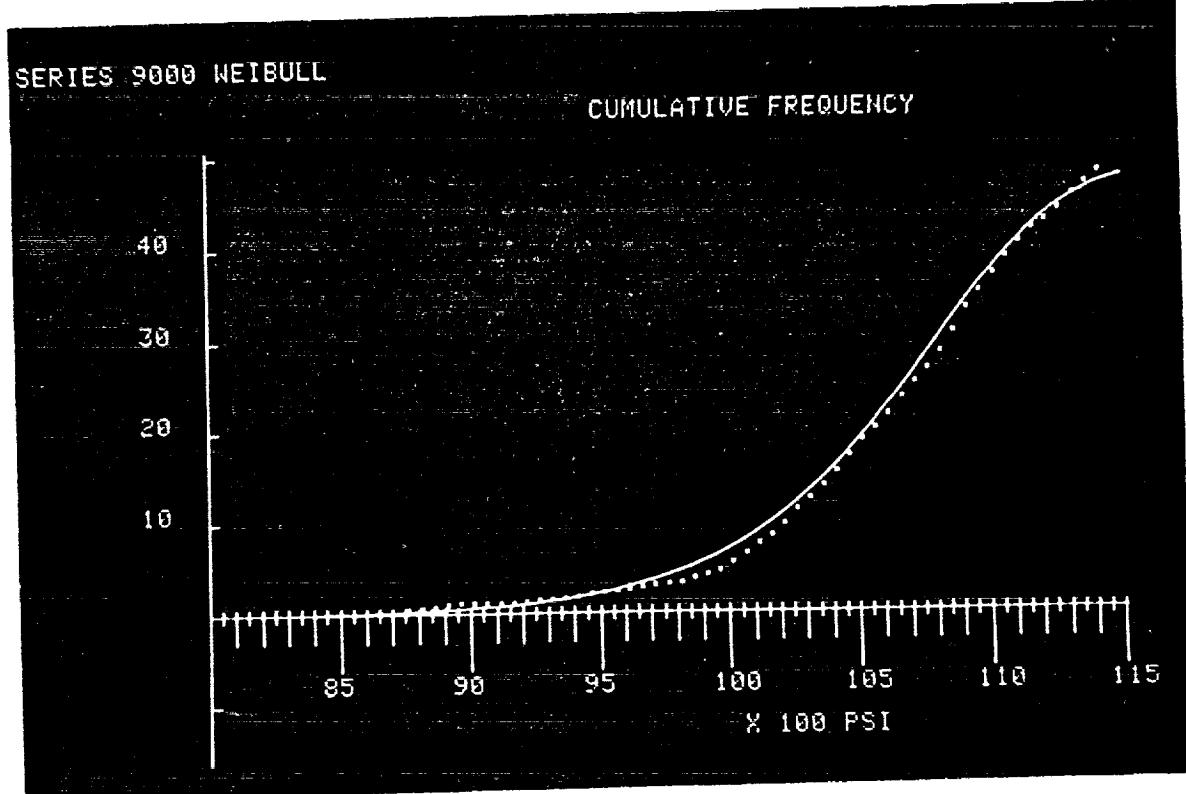
SERIES 9000 NORMAL

CUMULATIVE FREQUENCY

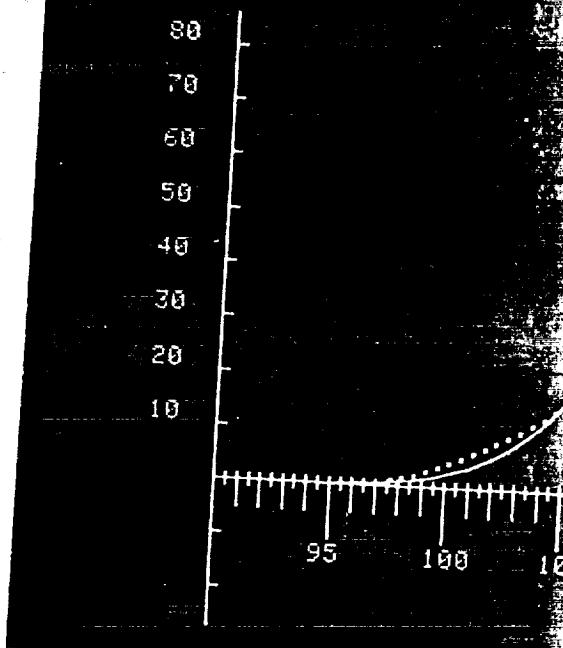


SERIES 9000 WEIBULL

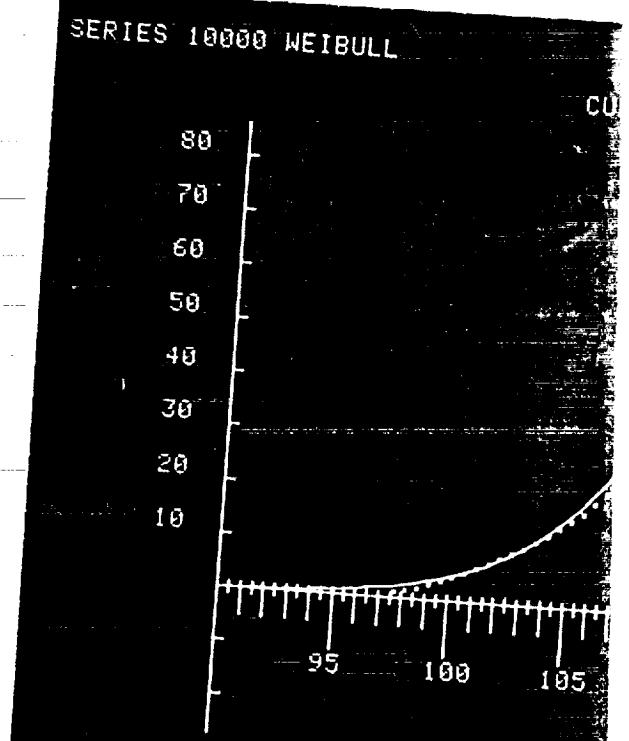
CUMULATIVE FREQUENCY



SERIES 10000 NORMAL



SERIES 10000 WEIBULL



SERIES 11000 NORMAL

CUMULATIVE FREQUENCY

80  
70  
60  
50  
40  
30  
20  
10

115 120 125 130 135 140 145 150 155 160

X 100 PSI

SERIES 11000 WEIBULL

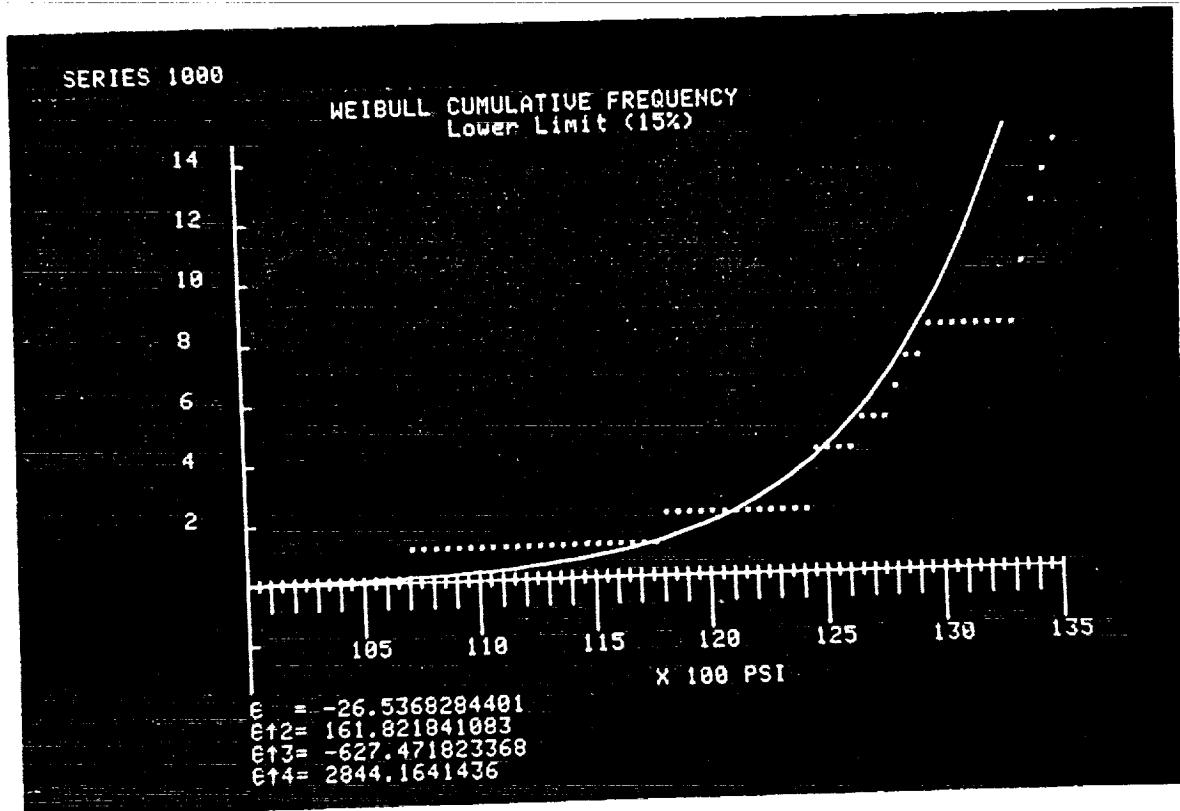
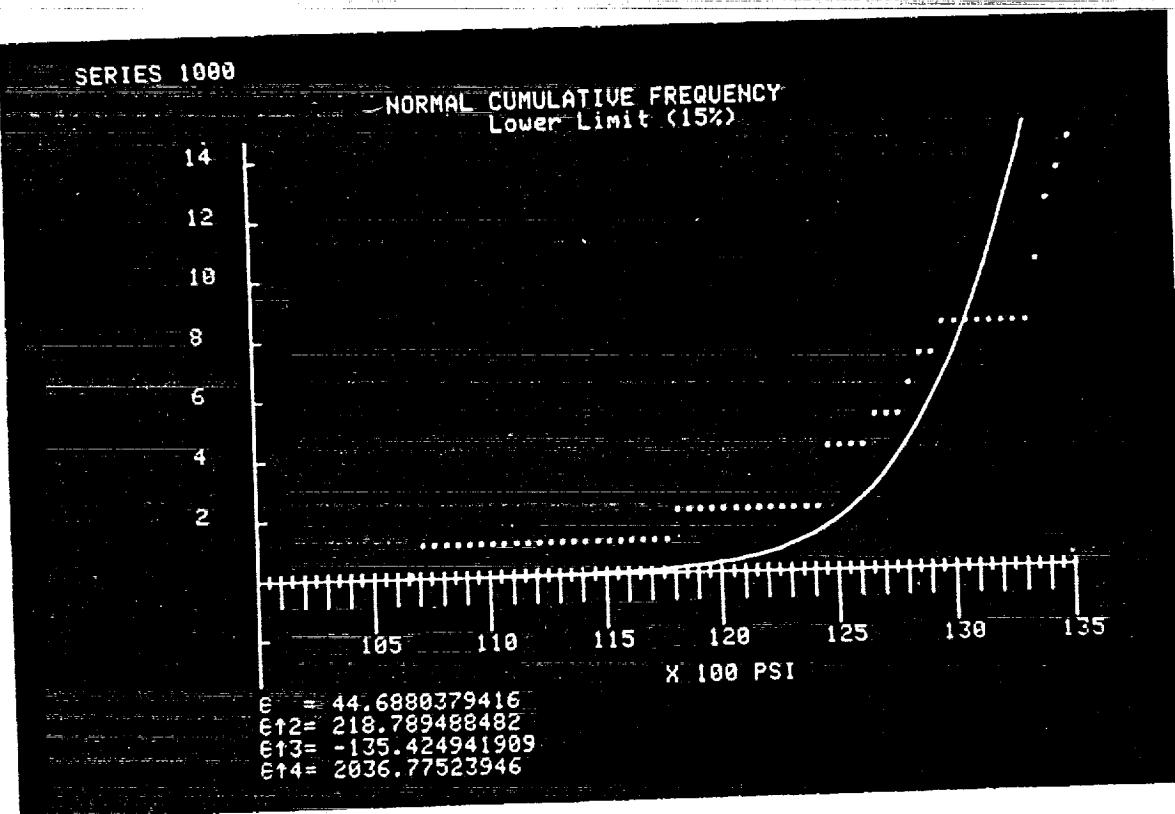
CUMULATIVE FREQUENCY

80  
70  
60  
50  
40  
30  
20  
10

115 120 125 130 135 140 145 150 155 160

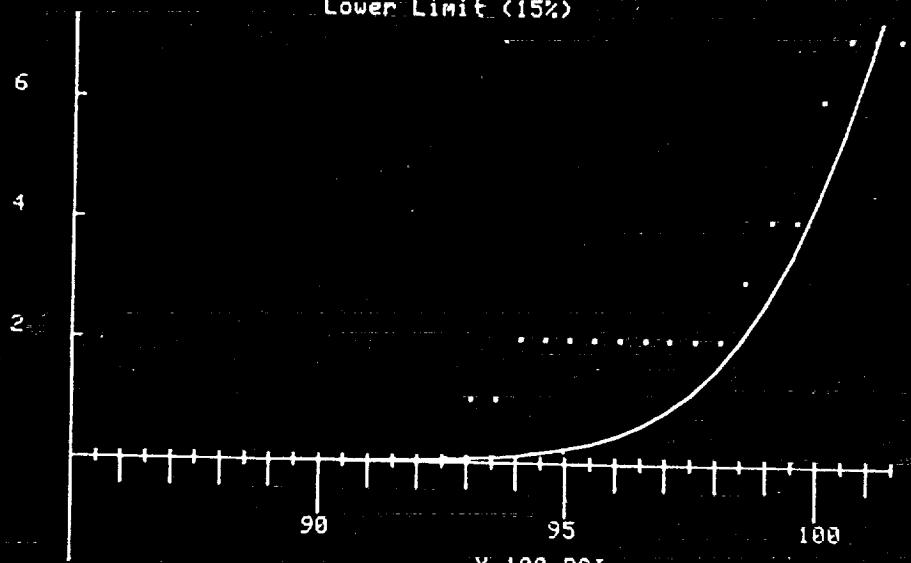
X 100 PSI

**SECTION V.**



SERIES 2000

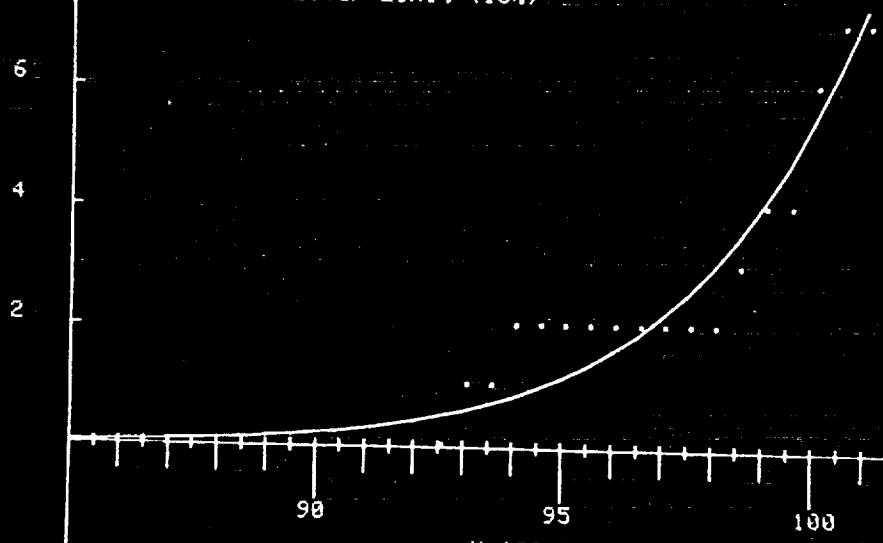
NORMAL CUMULATIVE FREQUENCY  
Lower Limit (15%)



$\bar{e} = 27.2252776684$   
 $e_{12} = 47.1608420194$   
 $e_{13} = 88.8662136529$   
 $e_{14} = 179.168934803$

SERIES 2000

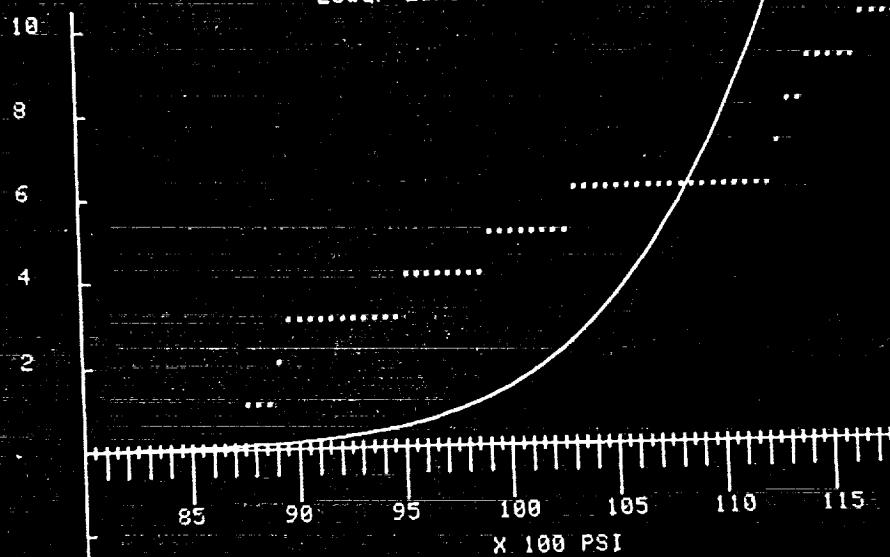
WEIBULL CUMULATIVE FREQUENCY  
Lower Limit (15%)



$\bar{e} = 8.38071704983$   
 $e_{12} = 10.7031872461$   
 $e_{13} = 10.983866047$   
 $e_{14} = 14.038049739$

SERIES 3000

NORMAL CUMULATIVE FREQUENCY  
Lower Limit (15%)



$$E_1 = 39.931785584$$

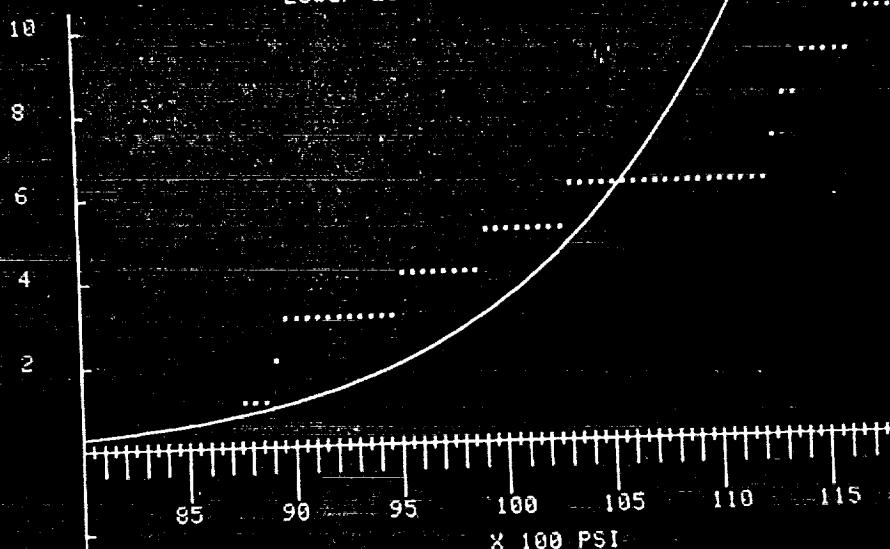
$$E_{12} = 766.805180367$$

$$E_{13} = -1612.16373362$$

$$E_{14} = 23016.3274267$$

SERIES 3000

WEIBULL CUMULATIVE FREQUENCY  
Lower Limit (15%)



$$E_1 = -49.4573152609$$

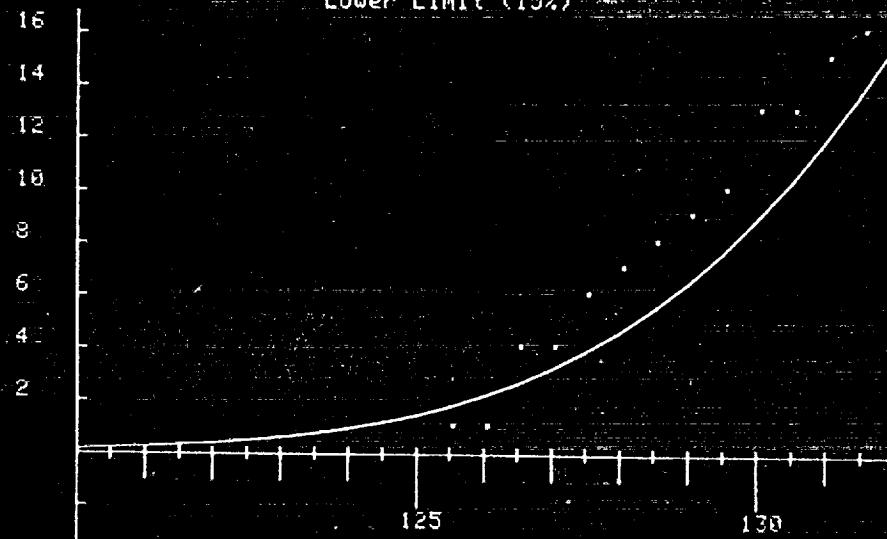
$$E_{12} = 621.82394888$$

$$E_{13} = -3110.56091382$$

$$E_{14} = 21596.5619169$$

SERIES 4000

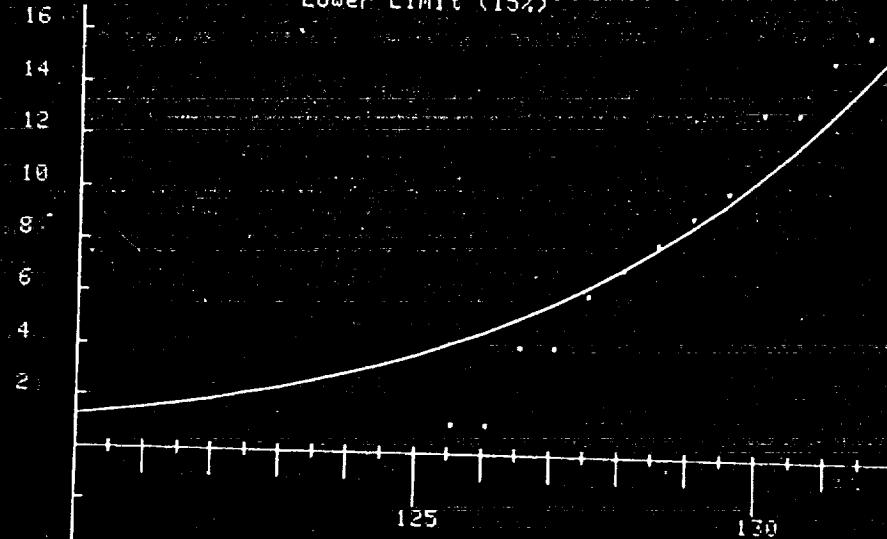
NORMAL CUMULATIVE FREQUENCY  
Lower Limit (15%)



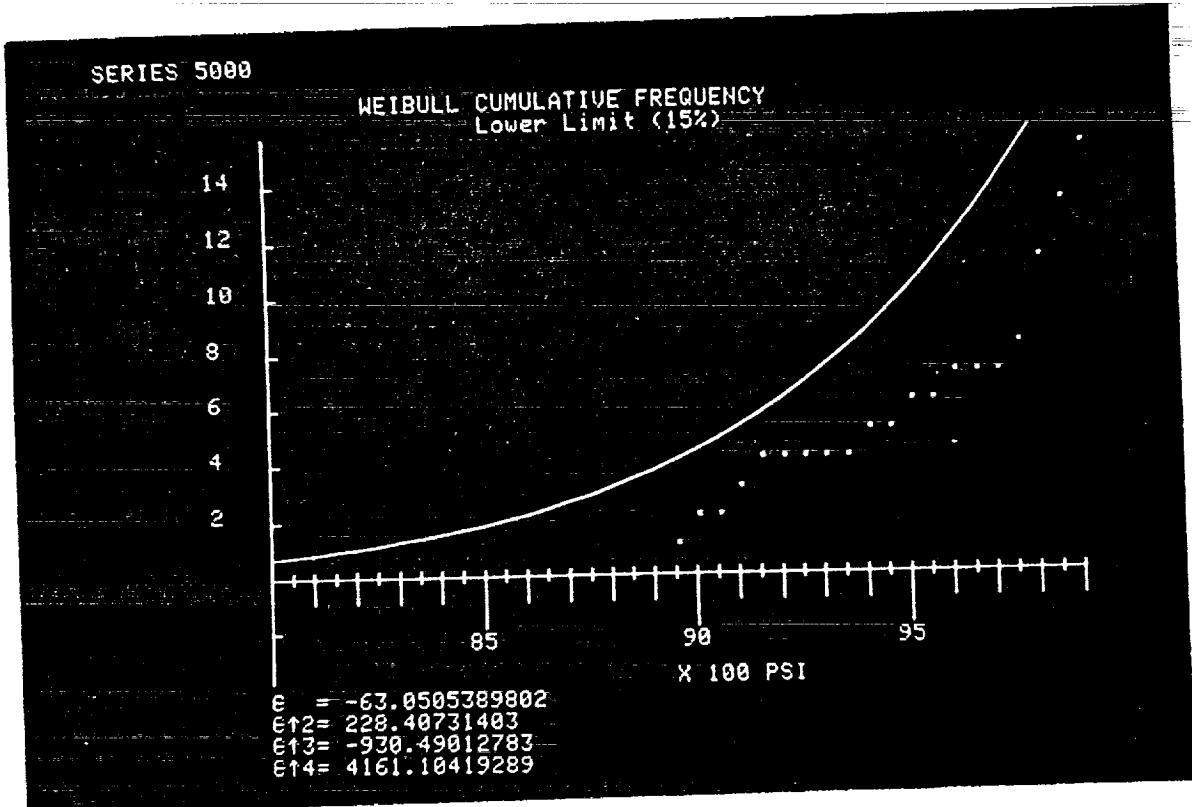
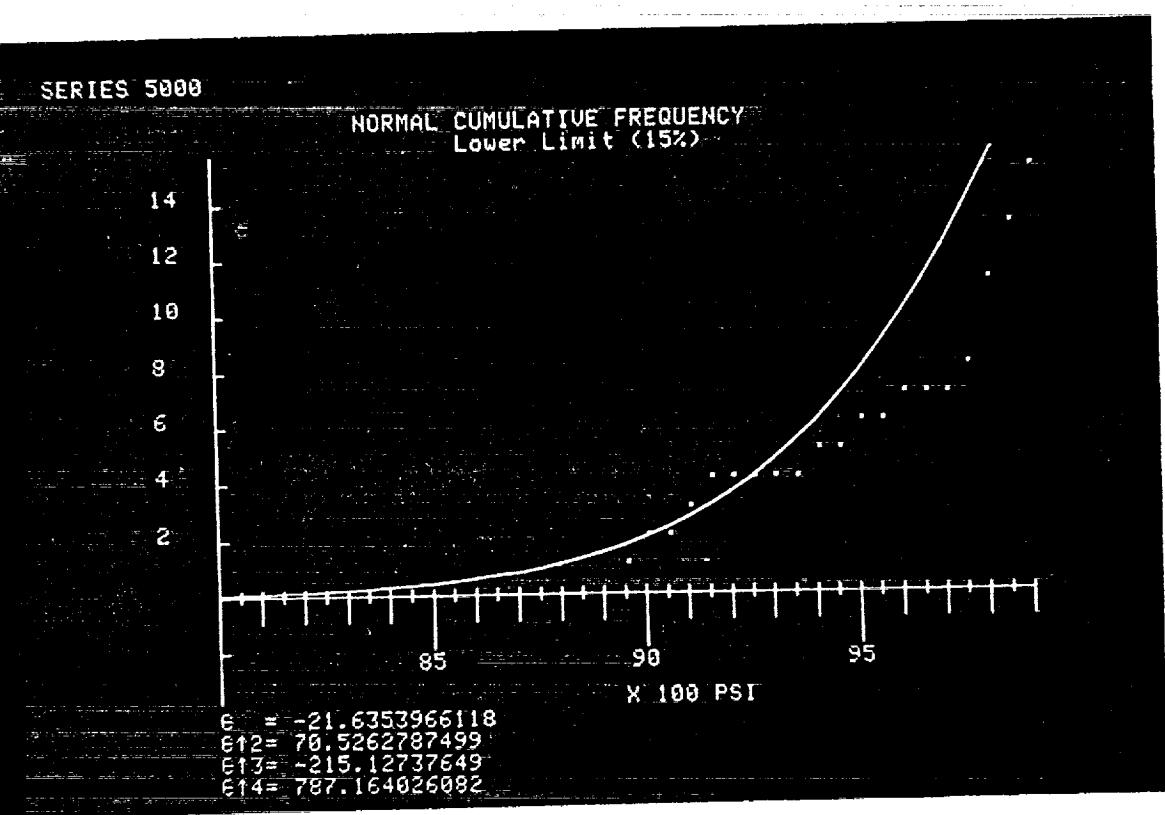
$\bar{E}_1 = 38.0069045753$   
 $\bar{E}_{12} = 144.459557643$   
 $\bar{E}_{13} = 564.872774696$   
 $\bar{E}_{14} = 2360.45404417$

SERIES 4000

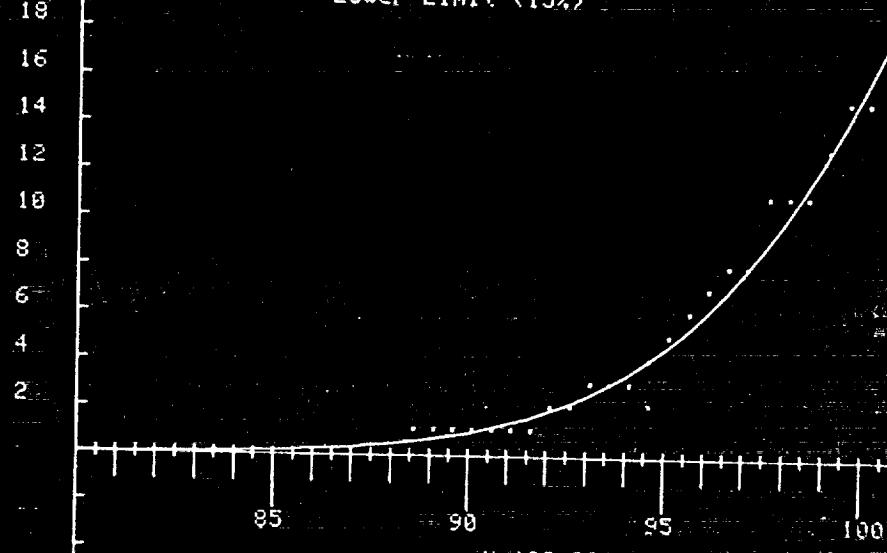
WEIBULL CUMULATIVE FREQUENCY  
Lower Limit (15%)



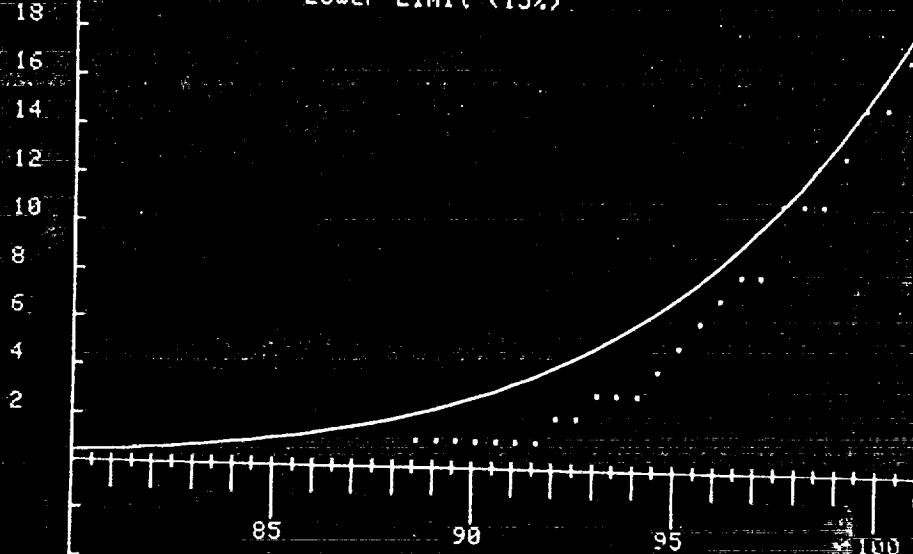
$\bar{E}_1 = 10.0975165556$   
 $\bar{E}_{12} = 63.5227752667$   
 $\bar{E}_{13} = 67.3406991326$   
 $\bar{E}_{14} = 534.514344197$

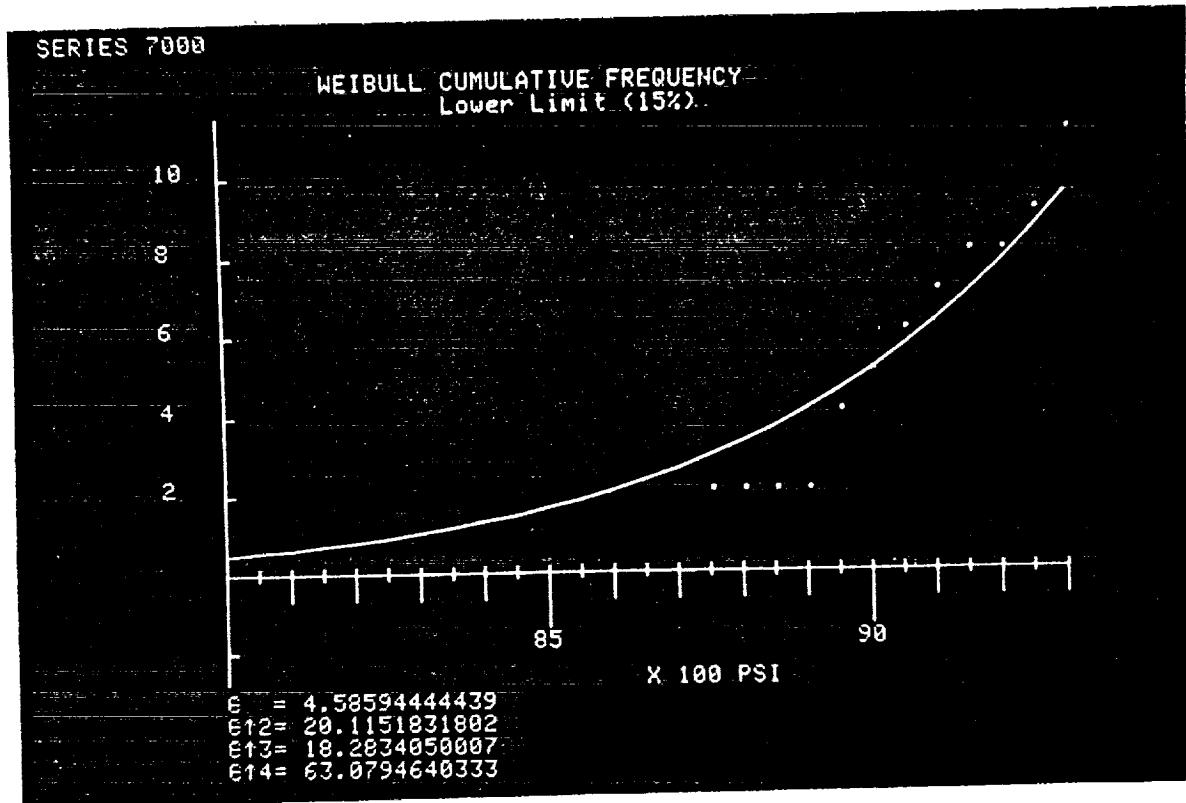
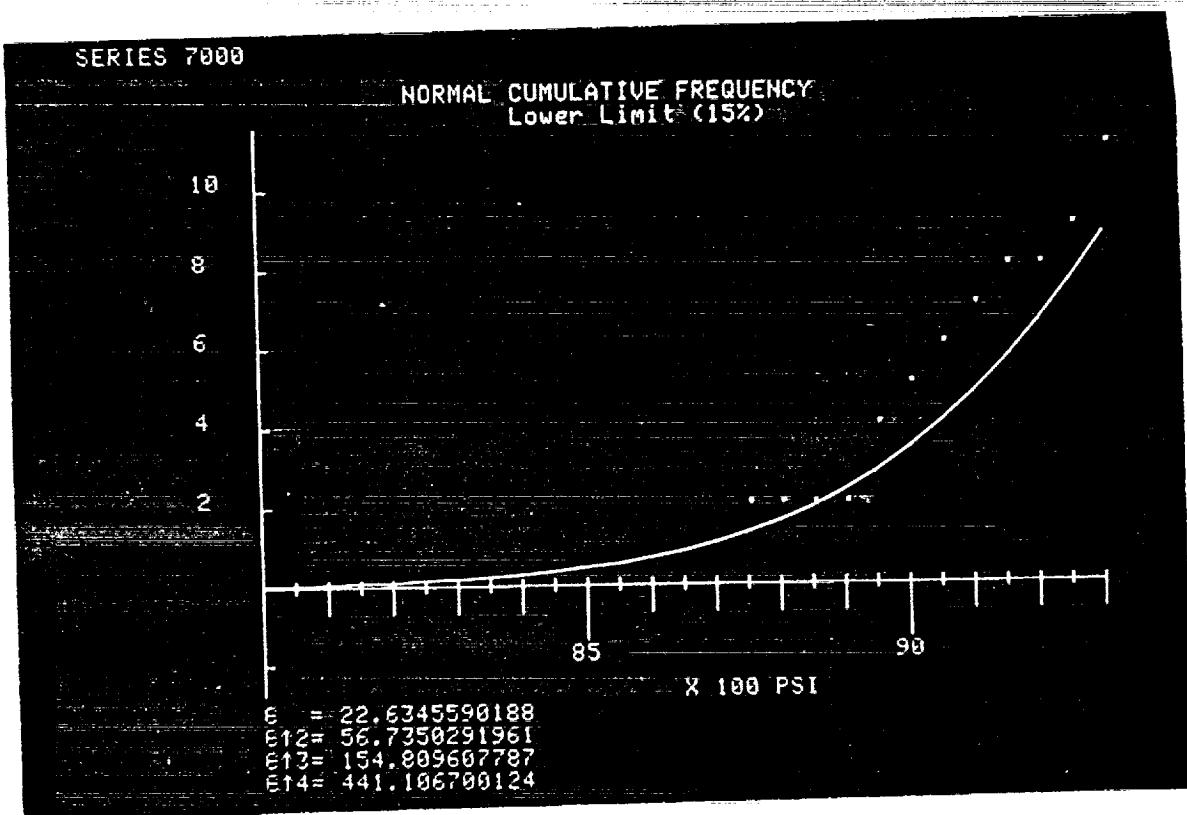


## SERIES 6000

NORMAL CUMULATIVE FREQUENCY  
Lower Limit (15%)
 $\bar{E} = 22.0347101799 \times 100 \text{ PSI}$   
 $E_{12} = 36.2644567401$   
 $E_{13} = 72.8771526998$   
 $E_{14} = 169.276570833$ 

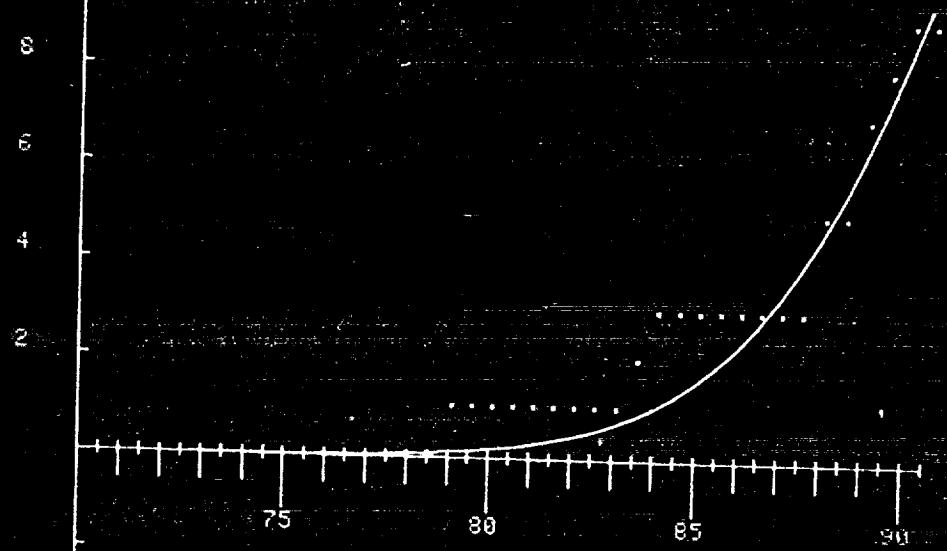
## SERIES 6000

WEIBULL CUMULATIVE FREQUENCY  
Lower Limit (15%)
 $\bar{E} = -26.8880964935 \times 100 \text{ PSI}$   
 $E_{12} = 57.3879810976$   
 $E_{13} = -104.002972187$   
 $E_{14} = 222.858547593$



SERIES 8000

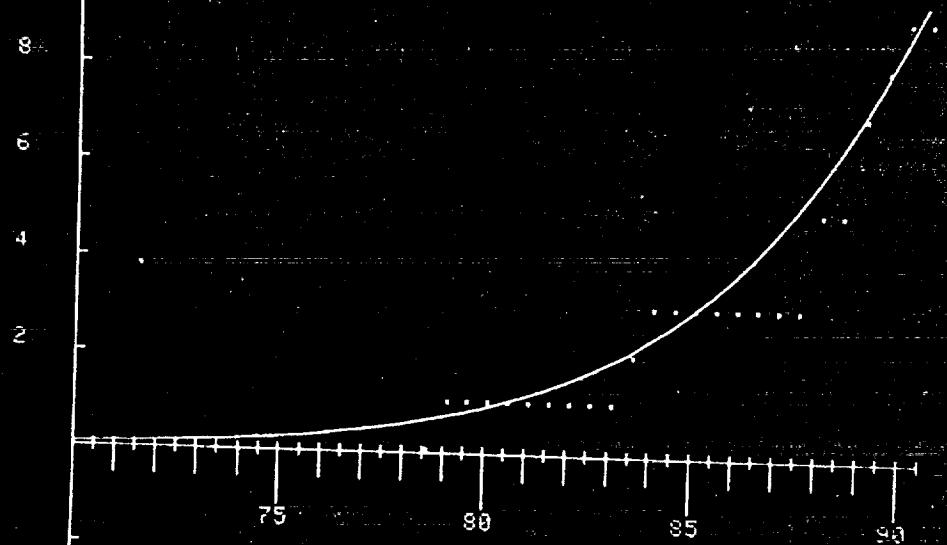
NORMAL CUMULATIVE FREQUENCY  
Lower Limit (15%)



$E_1 = 22.9690048514$   
 $E_{12} = 30.251396298$   
 $E_{13} = 44.7841484008$   
 $E_{14} = 73.1731397262$

SERIES 8000

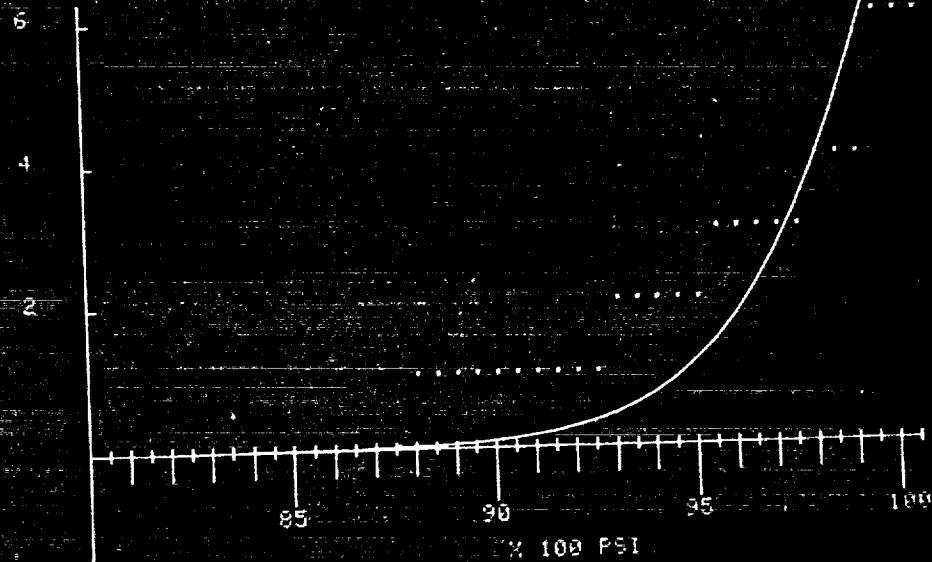
WEIBULL CUMULATIVE FREQUENCY  
Lower Limit (15%)



$E_1 = -1.948519593$   
 $E_{12} = 10.9885169535$   
 $E_{13} = -4.6395651917$   
 $E_{14} = 14.4523955448$

SERIES 9000

NORMAL CUMULATIVE FREQUENCY  
Lower Limit (15%)



$$E_1 = 20.2074771336$$

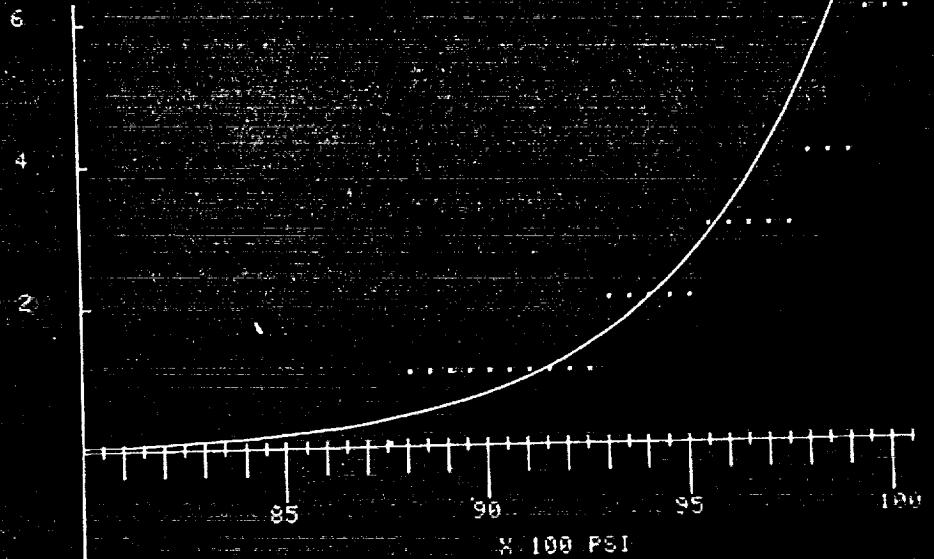
$$E_{12} = 29.8591994761$$

$$E_{13} = 38.2743653643$$

$$E_{14} = 54.359587165$$

SERIES 9000

WEIBULL CUMULATIVE FREQUENCY  
Lower Limit (15%)

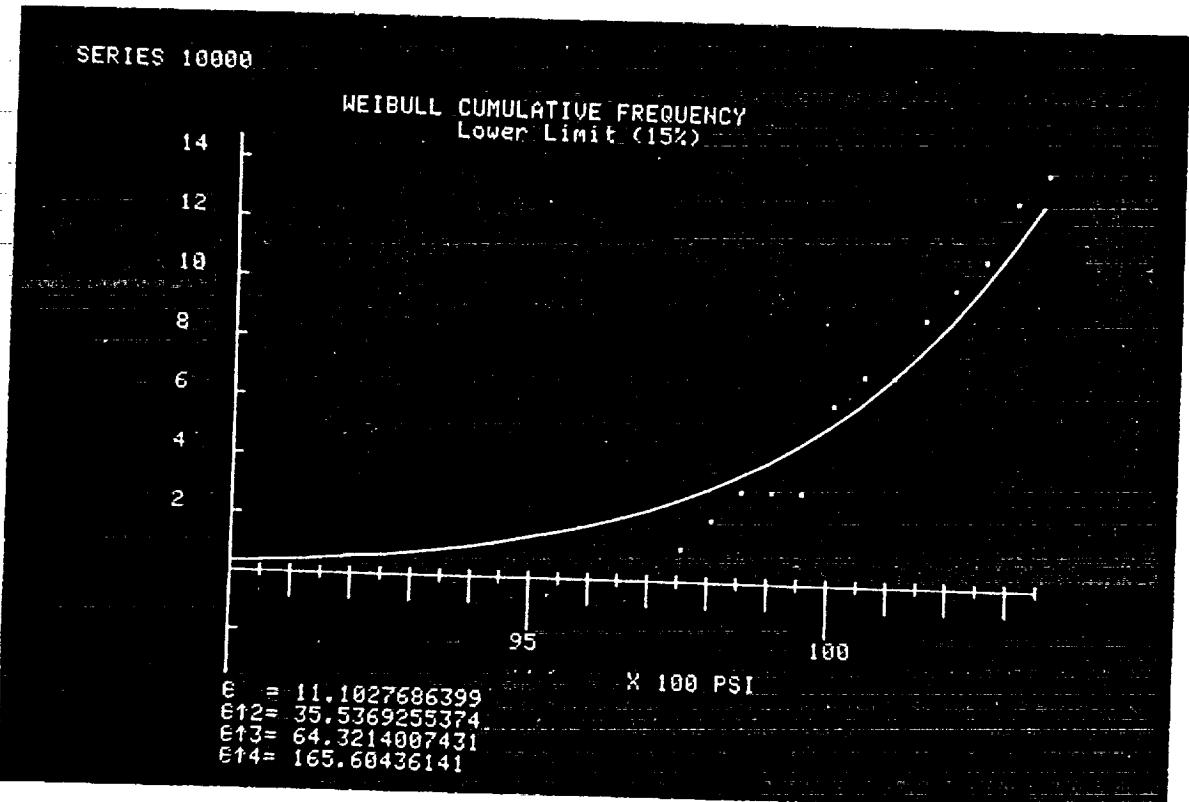
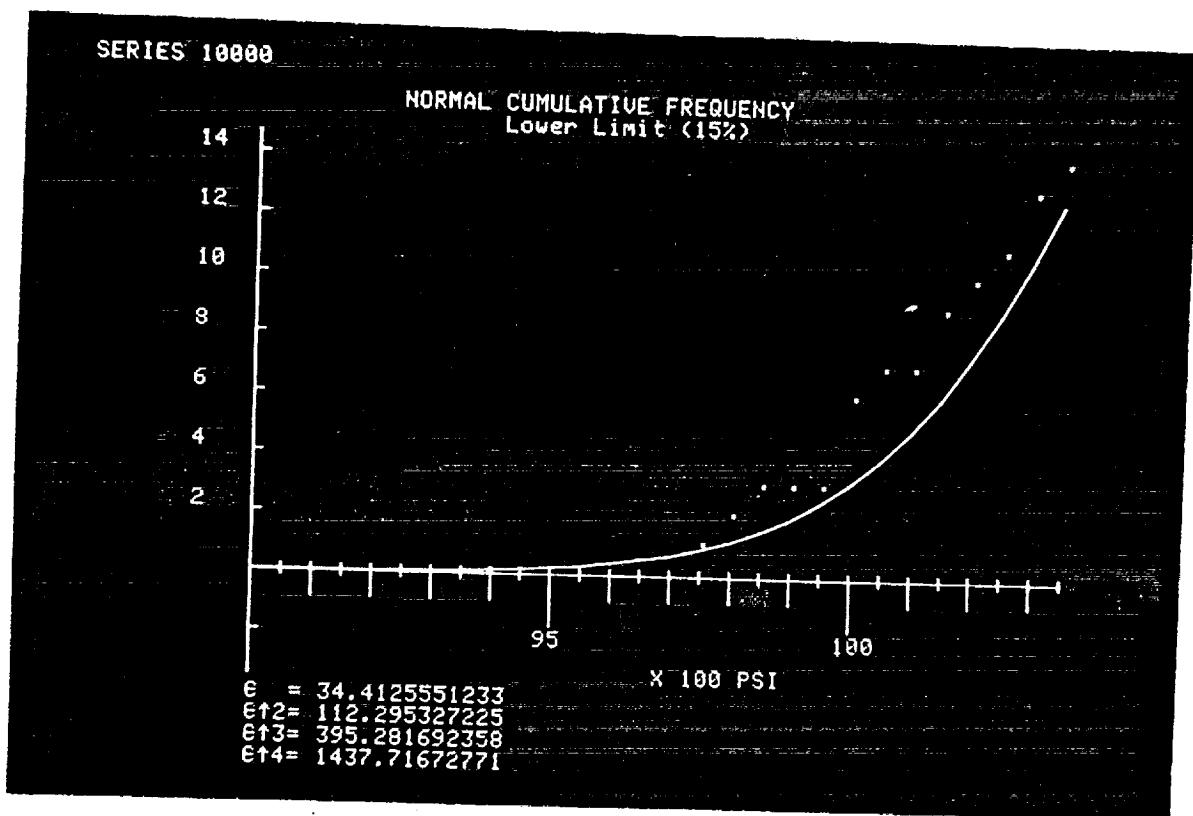


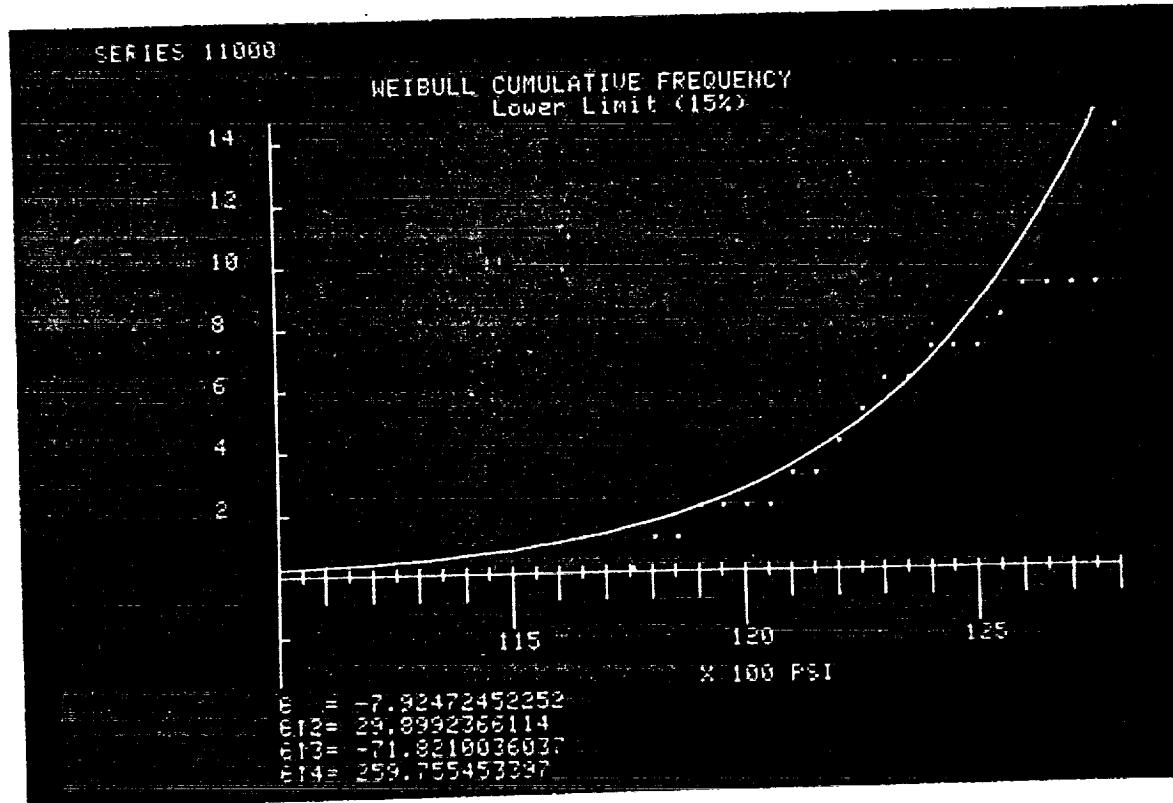
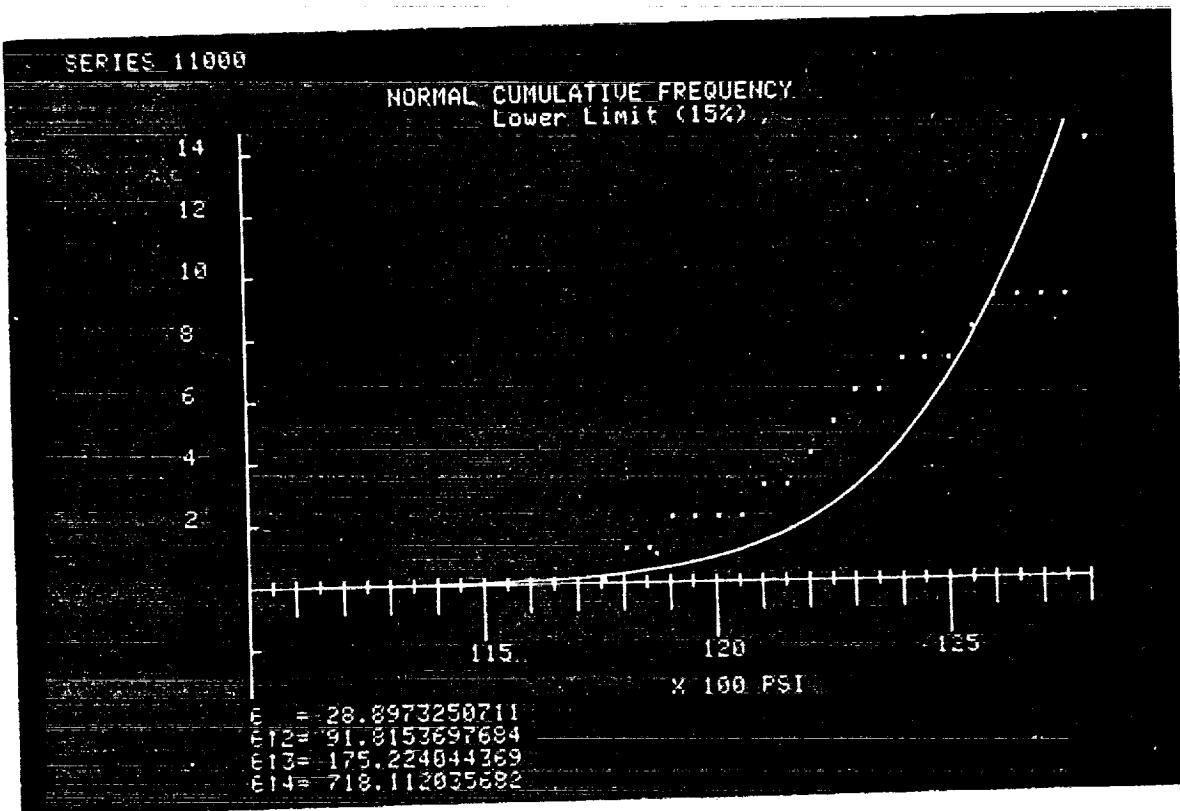
$$E_1 = -4.83727232951$$

$$E_{12} = 14.0665128556$$

$$E_{13} = -16.5475906362$$

$$E_{14} = 29.9631975455$$





APPENDIX D  
STATISTICAL ANALYSIS PROGRAM (BASIC)

FILE 1: Series 1000 Data  
FILE 2: Series 2000 Data  
FILE 3: Series 3000 Data  
FILE 4: Series 4000 Data  
FILE 5: Series 5000 Data  
FILE 6: Series 6000 Data  
FILE 7: Series 7000 Data  
FILE 8: Series 8000 Data  
FILE 9: Series 9000 Data  
FILE 10: Series 10000 Data  
FILE 11: Series 11000 Data  
  
FILE 12: Weibull Parameters Determination  
  
FILE 13: Intermediate Sorted Data Storage  
  
FILE 14: Output of Statistical Parameters  
FILE 15: Histogram Plots  
  
FILE 16: Absolute Frequency Data Storage  
FILE 17: Cumulative Frequency Data Storage  
FILE 18: Absolute Frequency (Moving Average) Data Storage  
FILE 19: Cumulative Frequency (Moving Average) Data Storage  
  
FILE 20: Absolute Frequency Distribution Comparison  
FILE 21: Cumulative Frequency Distribution Comparison  
  
FILE 22: Normal Distribution Data  
FILE 23: Weibull Distribution Data  
  
FILE 24: Extreme Value Comparison  
FILE 25: Random Sample Evaluation

## FILE 12. WEIBULL PARAMETERS DETERMINATION

```
100 INITIAL
110 PAGE
120 PRINT "WHICH SERIES DO YOU WANT?"
130 INPUT R
140 R = R/1000
150 FIND R
160 READ @33: X,E
170 DIM A(E)
180 READ @33: A
185 REM DATA SORTER
190 Z1=0
200 J=1.0E+300
210 FOR I=Z1 TO E
220 IF J < A(I) THEN 250
230 J= A(I)
240 K=I
250 NEXT I
260 FOR I=Z1+1 TO K
270 Q=K+Z1-I+1
280 IF Q <=1 THEN 300
290 A(Q)=A(Q-1)
300 NEXT I
310 A(Z1)=J
320 Z1=Z1+1
330 IF Z1>E THEN 360
340 J=A(Z1)
350 GO TO 260
255 REM CALCULATE WEIBULL PARAMETERS
360 X1=0
370 X2=0
380 Y1=0
390 Y2=0
400 FOR I=1 TO E
410 M=(I-0.3)/(E+0.4)
420 Y=LOG(LOG(1/(1-M)))
430 X=LOG(A(I))
440 X1=X1+X
450 Y1=Y1+Y
460 X2=X2+X+2
470 Y2=Y2+X*Y
480 NEXT I
490 L=(Y2*E-X1*Y1)/(E*X2-X1+2)
500 P=(Y1-L*X1)/E
510 S3=EXP(-P/L)
520 FIND 13
530 WRITE @33: E,L,S3,A
540 FIND 14
550 OLD
```

FILE 14: OUTPUT OF STATISTICAL PARAMETERS

```
100 FIND 13
110 READ @33: E,L,S3
120 DIM A(E)
130 READ @33: A
140 X2=0
150 FOR I=1 TO E
160 X2=X2+A(I)+2
170 NEXT I
180 M=SUM(A)/E
190 V=(X2-SUM(A)+2/E)/(E-1)
200 S=V^0.5
210 PAGE
220 MOVE 10,80
230 PRINT "NORMAL DISTRIBUTION:"
240 MOVE 20,70
250 PRINT "MEAN= ";
260 PRINT USING "6D":M
270 MOVE 20,60
280 PRINT "VARIENCE= ";
290 PRINT USING "9D":V
300 MOVE 20,50
310 PRINT "STANDARD DEVIATION= ";
320 PRINT USING "6D":S
330 MOVE 10,40
340 PRINT "WEIBULL DISTRIBUTION:"
350 MOVE 20,30
360 PRINT "SHAPE FACTOR= ";
370 PRINT USING "4D.3D":L
380 MOVE 20,20
390 PRINT "SCALE FACTOR= ";
400 PRINT USING "6D": S3
410 MOVE 20,10
420 PRINT "MINIMUM STRENGTH= ";
430 PRINT USING "6D":A(1)
440 MOVE 5,5
450 PRINT "PRESS RETURN TO CONTINUE";
460 FIND 13
470 WRITE @33: E,A,M,S,L,S3
480 FIND 15
490 INPUT A$
500 OLD
```

## FILE 15. HISTOGRAM PLOTS

```
100 FIND 13
110 PAGE
120 READ @33: E
130 DIM A(E)
140 READ @33: A
150 N1=INT(A(1)/100)
160 N2=INT(A(E)/100+1)
170 N=INT((N2-N1)*2+2)
180 DELETE A
185 REM ABSOLUTE FREQUENCY HISTOGRAM
190 GOSUB 1000
200 DELETE A
210 GOSUB 1500
220 FIND 16
230 WRITE @33: N,P2,K
240 N3=5*INT(N1/5)
250 N4=5*INT(N2/5)+5
260 WINDOW N3,N4,-P2/4,P2
270 VIEWPORT 20,100,15,90
280 D=1
290 GOSUB 2000
300 GOSUB 2500
310 GOSUB 3500
320 FOR I=2 TO N
330 K(I) = K(I)+K(I-1)
340 NEXT I
345 REM CUMULATIVE FREQUENCY HISTOGRAM
350 GOSUB 1500
360 FIND 17
370 WRITE @33: N,P2,K
380 INPUT A$
390 PAGE
400 WINDOW N3,N4,-P2/4,P2
410 D=2
420 GOSUB 2000
430 GOSUB 2500
440 GOSUB 3500
450 DELETE K
455 REM ABSOLUTE FREQUENCY (Moving Average) HISTOGRAM
460 FIND 16
470 READ @33: N,P2
480 DIM K2(N+6)
490 K2=0
500 REM
510 REM
520 REM
530 FOR I=4 TO N+3
540 READ @33: K
550 K2(I)=K
560 NEXT I
```

```

570 DELETE K
580 DIM K(N)
590 FOR I=1 TO N
600 K(I)=0
610 FOR J=0 TO 5
620 K(I)=K(I)+K2(I+J)/7
630 NEXT J
640 NEXT I
650 GOSUB 1500
660 FIND 18
670 WRITE @33: N,P2,K
680 INPUT A$
690 PAGE
700 WINDOW N3,N4,-P2/4,P2
710 D=3
720 GOSUB 2000
730 GOSUB 2500
740 GOSUB 3500
750 FOR I=2 TO N
760 K(I)=K(I)+K(I-1)
770 NEXT I
780 GOSUB 1500
790 FIND 19
800 WRITE @33: N,P2,K
810 INPUT A$
820 REM CULULATIVE GREQUENCY (Moving Average) HISTOGRAM
830 PAGE
840 WINDOW N3,N4,-P2/4,P2
850 D=4
860 GOSUB 2000
870 GOSUB 2500
880 GOSUB 3500
890 INPUT A$
900 PAGE
910 FIND 20
920 OLD

1000 REM DATA PARTITIONING
1010 FIND 13
1020 READ @33: E
1030 DIM K(N)
1040 K=0
1050 READ @33: A
1060 X=1
1070 FOR I=1 TO N
1080 Y=N1*100+I*50
1090 IF A>Y THEN 1150
1100 K(I)=K(I)+1
1110 X=X+1
1120 IF X>E THEN 1160
1130 READ @33: A
1140 GO TO 1080
1150 NEXT I
1160 RETURN

```

```

1500 REM LOCATE MAXIMUM FREQUENCY VALUE
1510 P2=0
1520 FOR I=1 TO N
1530 IF K(I)<=P2 THEN 1550
1540 P2=K(I)
1550 NEXT I
1560 RETURN

2000 REM GENERATE AXIS
2010 GO TO D OF 2020,2040,2060,2080
2020 AXIS 0.5,2,N3,0
2030 RETURN
2040 AXIS 0.5,10N3,0
2050 RETURN
2060 AXIS 0.5,2,N3,0
2070 RETURN
2080 AXIS 0.5,10,N3,0
2090 RETURN

2500 REM LABEL HISTOGRAM
2510 N3=5*INT(N1/5)+5
2520 MOVE N3,0
2530 FOR I=1 TO N STEP 10
2540 RDRAW 0,-P2/16
2550 PRINT "J";N3;
2560 N3=N3+5
2570 MOVE N3,0
2580 NEXT I
2590 N3=5*INT(N1/5)
2600 MOVE N3,0
2610 FOR I=N3 TO N4 STEP 1
2620 RDRAW 0,-P2/32
2630 N3=N3+1
2640 MOVE N3,0
2650 NEXT I
2660 N3=5*INT(N1/5)
2670 GO TO D OF 2680,2770,2860,2980
2680 FOR I=2 TO P2 STEP 2
2690 MOVE N3,I
2700 PRINT "HH";I;
2710 NEXT I
2720 MOVE (N2-N1)/2+N1,0
2730 PRINT "JJJJJ";"X 100 PSI";
2740 MOVE (N2-N1)/2+N1,P2
2750 PRINT "KK";"ABSOLUTE FREQUENCY";
2760 RETURN
2770 FOR I=10 TO P2 STEP 10
2780 MOVE N3,I
2790 PRINT "HHHH";I;
2800 NEXT I
2810 MOVE (N2-N1)/2+N1,0

```

```
2820 PRINT "JJJJ";"X 100 PSI";
2830 MOVE (N2-N1)/2+N1,P2
2840 PRINT "K";"HHHH";"CUMULATIVE FREQUENCY";
2850 RETURN
2860 MOVE N3,0
2870 FOR I=2 TO P2 STEP 2
2880 MOVE N3,I
2890 PRINT "HHHH";I;
2900 NEXT I
2910 MOVE (N2-N1)/2+N1,0
2920 PRINT "JJJJ";"X 100 PSI";
2930 MOVE (N2-N1)/2+N1,P2
2940 PRINT "KK";"HHHHHH";"ABSOLUTE FREQUENCY";
2950 MOVE (N2-N1)/2+N1,P2
2960 PRINT "K";"HHHHHH";"(Moving Average)";
2970 RETURN
2980 FOR I=10 TO p2 STEP 10
2990 MOVE N3,I
3000 PRINT "HHHH";I;
3010 NEXT I
3020 MOVE (N2-N1)/2+N1,0
3030 PRINT "JJJJ";"X 100 PSI";
3040 MOVE (N2-N1)/2+N1,P2
3050 PRINT "K";"HHHHHH";"CUMULATIVE FREQUENCY";
3060 MOVE (N2-N1)/2+N1,P2
3070 PRINT "HHHHHH";"(Moving Average)";
3080 RETURN

3500 REM GENERATE HISTOGRAM
3510 MOVE N1,0
3520 FOR I=1 TO N
3530 RDRAW 0,K(I)
3540 RDRAW 0.5,0
3550 RDRAW 0,-K(I)
3560 NEXT I
3570 RETURN
```

FILE 20. ABSOLUTE FREQUENCY DISTRIBUTION COMPARISON

```
100 FIND 13
110 PAGE
120 READ @33: E
130 DIM A(E)
140 READ @33: A
150 GOSUB 1000
160 DELETE A
170 READ @33:M,S,L,S3
180 GOSUB 1500
190 GOSUB 2000
200 GOSUB 2500
210 GOSUB 3000
220 GOSUB 3500
230 INPUT A$
240 FIND 21
250 OLD

1000 REM CALCULATE GRAPHING LIMITS
1010 N1=INT(A1)/100
1020 N2=INT(A(E)/100+1)
1030 N3=5*INT(N1/5)-5
1040 N4=%*INT(N2/5)+5
1050 N=(N2-N1)*2
1060 RETURN

1500 REM GENERATE AXIS
1510 DIM K(N)
1520 FIND 18
1530 READ @33: U,P2,K
1540 Z=SUM(K)
1550 WINDOW N3,N4,-P2/4,P2*1.01
1560 VIEWPORT 20,110,20,85
1570 AXIS 0.5,1,N3,0
1580 RETURN

2000 REM LABEL GRAPH
2010 MOVE (N2-N1)/2+N1,P2
2020 PRINT "KK";"HHHHHH";"ABSOLUTE FREQUENCY";
2030 FOR I=1 TO P2
2040 MOVE N3,I
2050 PRINT "HHHHHH";I;
2060 NEXT I
2070 MOVE (N2-N1)/2+N1,0
2080 PRINT "JJJJ";"X 100 PSI";
2090 FOR I=N3 TO N4 STEP 1
2100 MOVE I,0
2110 RDRAW 0,-P2/6
2120 NEXT I
2130 FOR I=N3+5 TO N4 STEP 5
2140 MOVE I,0
2150 RDRAW 0,-P2/8
```

```

2160 PRINT "J";"H";I;
2170 NEXT I
2180 RETURN

2500 REM PLOT DATA FREQUENCY
2510 X7=1
2520 FOR I=N1 TO N2-0.5 STEP 0.5
2530 IF K(X7)=0 THEN 2560
2540 MOVE I,K(X7)
2550 PRINT ".";
2560 X7=X7+1
2570 NEXT I
2580 RETURN

3000 REM GENERATE NORMAL DISTRIBUTION
3010 MOVE N3,0
3020 N5=N4-N3
3030 DELETE P
3040 DIM P(N5*2)
3050 P9=1/((2*PI)+0.5*5)
3060 FOR I=N3 TO N4-0.5 STEP 0.5
3070 P(I*2+1-N3*2)=P9*EXP(-((I*100-M)+2/(2*S+2)))
3080 ON SIZE THEN 3090
3090 NEXT I
3100 R=SUM(P)
3110 FOR I=1 TO N5*2
3120 P(I)=P(I)/R
3130 NEXT I
3140 FIND 22
3150 WRITE @33: N5*2,N1,N2,N3,N4,N,P
3160 N6=N3+0.5
3170 MOVE N3,0
3180 FOR I=1 TO 2*N5-1
3190 DRAW N6,P(I)*2
3200 N6=N6+0.5
3210 NEXT I
3220 RETURN

3500 REM GENERATE WEIBULL DISTRIBUTION
3510 MOVE N3,0
3520 DELETE P
3530 DIM P(N5*2)
3540 FOR I=1 TO 2*N5
3550 X5=I*50+N3*100
3560 P(I)= L*(X5+(L-1)/S3+L)*EXP(-((X5/S3)+L))
3570 ON SIZE THEN 3580
3580 NEXT I
3590 R=SUM(P)
3600 FOR I=1 TO N5*2
3610 P(I)=P(I)/R
3620 NEXT I
3630 FIND 23
3640 WRITE @33: N5*2,N1,N2,N3,N4,N,P

```

```
3650 N6=N3+.5
3660 MOVE N6,0
3670 FOR I=1 TO N5*2-1
3680 DRAW N6,P(I)*Z
3690 RMOVE 0,0.01*P2
3700 RDRAW 0,-0.02*P2
3710 RMOVE 0,0.01*P2
3720 N6=N6+0.5
3730 NEXT I
3740 RETURN
```

## FILE 21. CUMULATIVE FREQUENCY DISTRIBUTION COMPARISON

```
100 FIND 22
110 PAGE
120 D=0
130 READ @33: N5,N1,N2,N3,N4,N
140 DIM P(N5)
150 READ @33: P
160 FIND 19
170 DIM K(N)
180 READ @33: U,P2,K
190 WINDOW N3,N4,-P2/3,P2*1.05
200 VIEWPORT 20,120,20,90
210 AXIS 0.5,10,N3,0
220 MOVE N3,0
230 FOR I=10 TO P2 STEP 10
240 MOVE N3,0
230 FOR I=10 TO P2 STEP 10
240 MOVE N3,I
250 PRINT "HHHH";I;
260 NEXT I
270 MOVE N3,0
280 FOR I=1 TO N5/2
290 MOVE N3+I,0
300 RDRAW 0,-P2/16
310 NEXT I
320 MOVE N3,0
330 FOR I=1 TO N5/10
340 MOVE N3+I*5,0
350 RDRAW 0,-P2/8
360 PRINT "J";"H";N3+I*5
370 NEXT I
380 MOVE (N2-N1)/2+N1,P2
390 PRINT "KK";"HHHHHH";"CUMULATIVE FREQUENCY";
400 MOVE (N2-N1)/2+N1,0
410 PRINT "JJJJJJ";"X 100 PSI";
420 FOR I=1 to N
430 MOVE N1+I*0.5,K(I)
440 PRINT ".";
450 NEXT I
460 FOR I=2 TO N5
470 P(I)=P(I)+P(I-1)
480 NEXT I
490 N7=N3+0.5
500 MOVE N3,0
510 FOR I=1 TO N5
520 DRAW N7,P(I)*K(N)
530 N7=N7+0.5
540 NEXT I
550 IF D=1 THEN 650
560 INPUT A$
570 PAGE
```

```
580 D=1
590 DELETE P
600 FIND 23
610 READ @33: N5,N1,N2,N3,N4,N
620 DIM P(N5)
630 READ @33: P
640 GO TO 190
650 INPUT A$
660 FIND 24
670 OLD
```

## FILE 24. EXTREME VALUE COMPARISON

```
100 FIND 22
110 PAGE
120 D=0
130 READ @33: N5,N1,N2,N3,N4,N
140 C9=N1
150 C8=N1-N3
160 FIND 17
170 DIM K(N)
180 READ @ 33: U,PZ,K
190 G=0.15*K(N)
200 C=0
210 FOR I=1 TO N
220 IF K(I)>G THEN 270
230 C=K(I)
240 G1=I
250 NEXT I
260 N4=N1+G1/2
270 WINDOW N3,N4,-C/4,C*1.05
280 VIEWPORT 20,120,20,90
290 AXIS 0.5,2,N3,0
300 MOVE N3,1
330 PRINT "HHHH"; I;
340 NEXT I
350 MOVE N3,0
360 FOR I=1 TO N4-N3
370 MOVE N3+I,0
380 RDRAW 0,-C/16
390 NEXT I
400 MOVE N3,0
410 FOR I=1 TO (N4-N3)/5
420 MOVE N3+I*5,0
430 RDRAW 0,-C/8
440 PRINT "J"; "H"; N3+I*5;
450 NEXT I
460 IF D=1 THEN 1040
470 MOVE N3,C
480 PRINT"KK";" NORMAL CUMULATIVE FREQUENCY";
490 MOVE N3,C
500 PRINT "K"; Lower Limit (15%)" ;
510 MOVE (N4-N3)/2+N3,0
520 PRINT "JJJJ"; "X 100 PSI",
530 G5=0
540 FOR I=1 TO G1
550 MOVE C9+I*0.5, K(I)
560 PRINT ".";
570 NEXT I
580 FIND 13
590 READ @ 33: E
600 FOR I=1 TO E
610 READ @ 33: Z
620 NEXT I
```

```

630 READ # 33: M5,S5,M6S6
640 MOVE N3,0
650 DIM P(G1*2)
655 REM GENERATE NORMAL DISTIRBUTION
660 C1=0.196854
670 C2=0.115194
680 C3=3.44E-4
690 C4=0.019527
700 U8=0
710 FOR X=N3*100 TO N4*100 STEP 50
720 T=ABS((X-M5)/S5)
730 P5=1/(2*(1+C1*T+C2*T^2+C3*T^3+C4*T^4)^4)
740 P6=P5*K(N)
750 IF X/100<N1 THEN 780
760 U8=U8+1
770 O(U8)=P6
780 DRAW X/100,P6
790 NEXT X
800 M1=0
810 M2=0
820 M3=0
830 M4=0
840 FOR I=1 TO G1
850 X=K(I)-O(I)
860 M1=M1+X
870 M2=M2+X+2
880 M3=M3+X+3
890 M4=M4+X+4
900 NEXT I
910 MOVE N3,0
920 PRINT "JJJJJJCH- =";M1
930 MOVE N3,0
940 PRINT "JJJJJJCH-+2=";M2
950 MOVE N3,0
960 PRINT "JJJJJJCH+3=";M3
970 MOVE N3,0
980 PRINT "JJJJJJCH+4=";M4
990 IF D=1 THEN 1280
1000 D=1
1010 INPUT A$
1020 PAGE
1030 GO TO 270
1040 MOVE N3,C
1050 PRINT "KK"; WEIBULL CUMULATIVE FREQUENCY";
1060 MOVE N3,C
1070 PRINT "K"; Lower Limit (15%)";
1080 MOVE (N4-N3)/2 + N3,0
1090 PRINT "JJJJ"; "X 100 PSI";
1100 G5=0
1110 FOR I=1 TO G1
1120 MOVE C9+I*0.5, K(I)
1130 PRINT ".";
1140 NEXT I

```

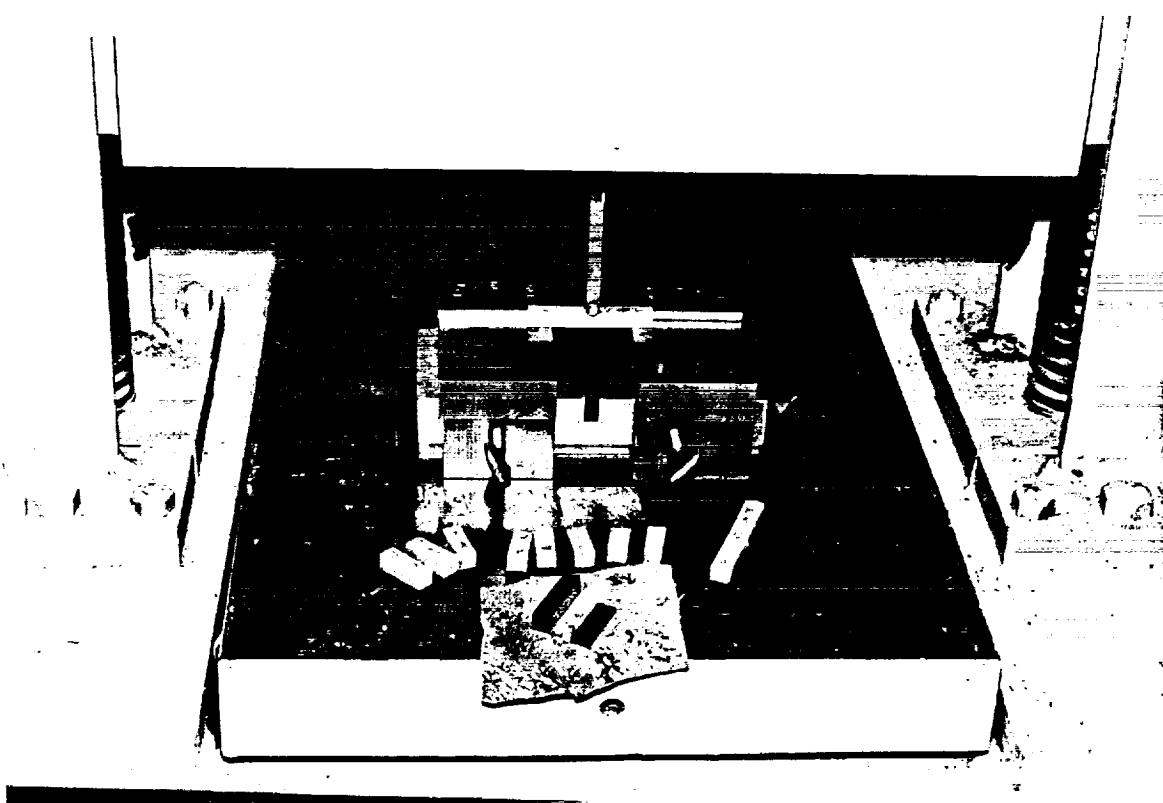
```
1150 DELETE O
1160 DIM O(G1*2)
1170 UP=0
1180 MOVE N3,0
1185 REM GENERATE WEIBULL DISTRIBUTION
1190 FOR X=N3*100 TO N4*100 STEP 50
1200 R=1-EXP(-((X/S6)^M6))
1210 P6=R*K(N)
1220 IF X/100<N1 THEN 1250
1230 U8=U8+1
1240 O(U8)=P6
1250 DRAW X/100,P6
1260 NEXT X
1270 GO TO 800
1280 END
```

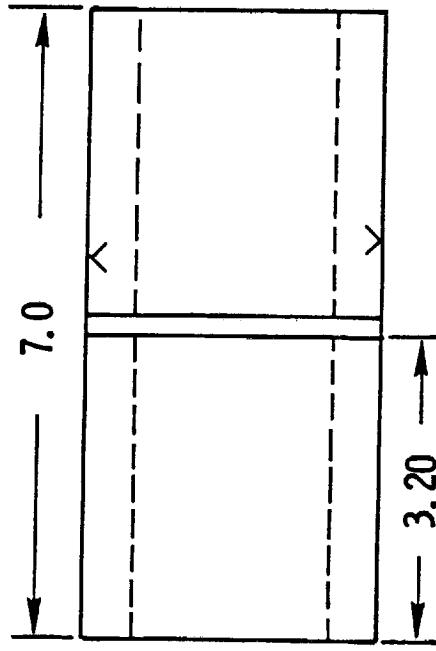
FILE 25: RANDOM SAMPLE EVALUATION

```
100 INITIAL
110 PRINT "HOW MANY ITERATIONS?";
120 INPUT W
130 PRINT "JJJJ WHAT PERCENTAGE VALUE?";
140 INPUT H
150 PAGE
160 A$="SAMPLE SIZE"
170 B$="SHAPE FACTOR"
180 C$="SCALE FACTOR"
190 D$="0.1% PERCENTAGE"
200 PRINT USING 210: A$,B$,C$,D$
210 IMAGE 11A,5X,12A,5X,12A,5X,18A
220 FOR Z=1 TO W
230 DELETE A,B
240 FIND 13
250 READ @ 33: N
260 DIM B(N)
270 READ @ 33: B
280 FOR I=1 TO N
290 R=RND(-1)
300 IF R<=H/100 THEN 320
310 B(I)=0
320 NEXT I
330 E=0
340 FOR I=1 TO N
350 IF B(I)=0 THEN 370
360 E=E+1
370 NEXT I
380 D=1
390 DIM A(E)
400 FOR I=1 TO N
410 IF B(I)=0 THEN 440
420 A(D)=B(I)
430 D=D+1
440 NEXT I
450 X1=0
460 X2=0
470 X1=0
480 Y2=0
490 FOR I=1 TO E
500 M=(I-0.3)/(E+0.4)
510 X=LOG(LOG(1/(1-M)))
520 X=LOG(A(I))
530 X1=X1+X
540 Y1=Y1+Y
550 X2=X2+X+2
560 Y2=Y2+X*Y
570 NEXT I
580 L=(Y2*E-X1*Y1)/(E*X2-X1+2)
590 P=(Y1-L*X1)/E
600 S3=EXP(-P/L)
```

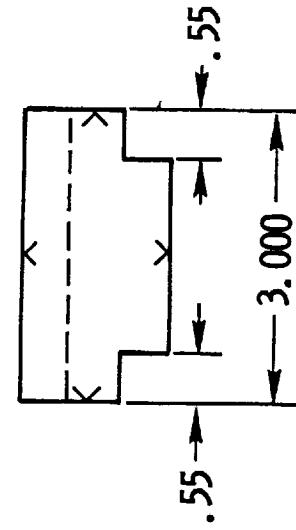
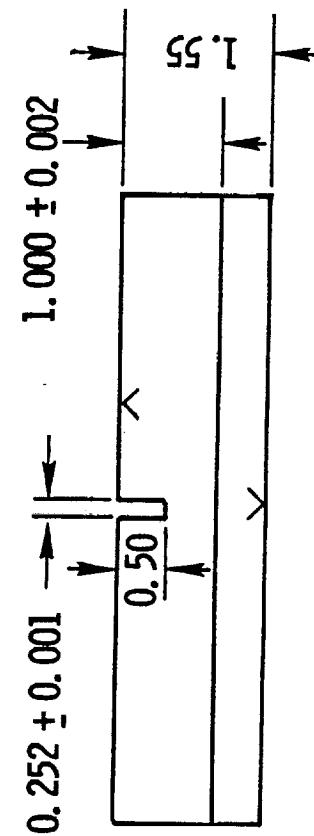
```
610 X2=0
620 FOR I=1 TO E
630 X2=X2+A(I)+2
640 NEXT I
650 M=SUM(A)/E
660 V=(X2-SUM(A)+2/E)/(E-1)
670 S=V+0.5
680 C1=0.196854
690 C2=0.115194
700 C3=3.44 E-4
710 C4=0.019527
720 X=6000
730 T=ABS((X-M)/S)
740 P5=1/(2*(1+C1*T+C2*T^2+C3*T^3+C4*T^4)+4)
750 IF P5>1.0E-3 THEN 790
760 R9=X
770 X=X+50
780 GO TO 730
790 X=6000
800 R=1-EXP(-((X/S3)+L))
810 IF>R 1.0E-3 THEN 850
820 R8=X
830 X=X+50
840 GO TO 800
850 PRINT USING 860: E,L,S3,R8,R9
860 IMAGE 3X,3D,11X,3D,12X,5D,11X,5D,3X,5D
870 NEXT Z
880 END
```

APPENDIX E  
SHORT-BEAM SHEAR TEST FIXTURE



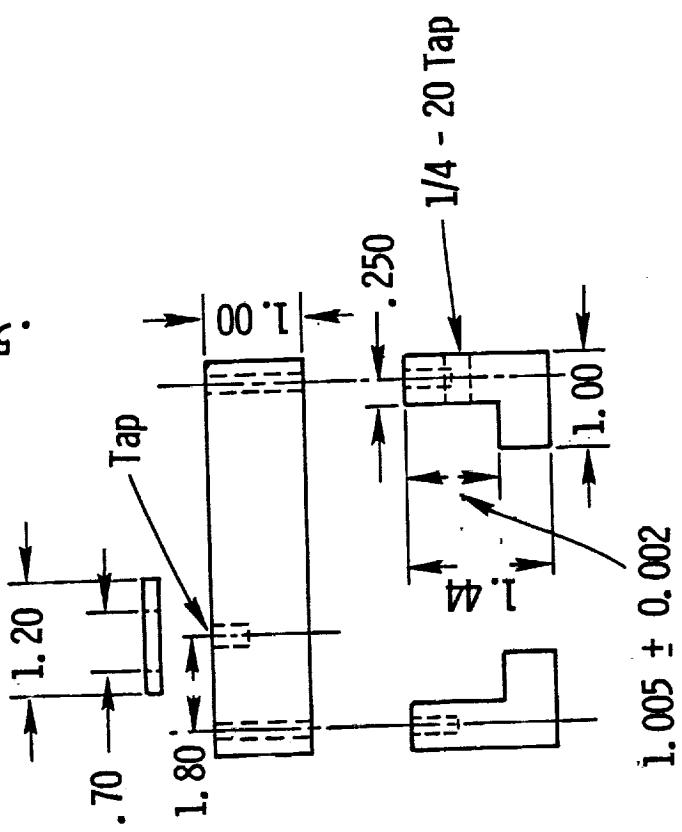
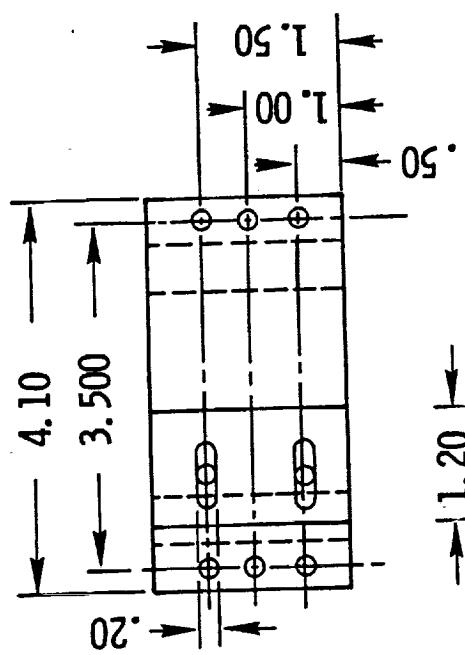


All lengths have tolerance of  $\pm .5$   
accuracy of dimension unless  
stated otherwise

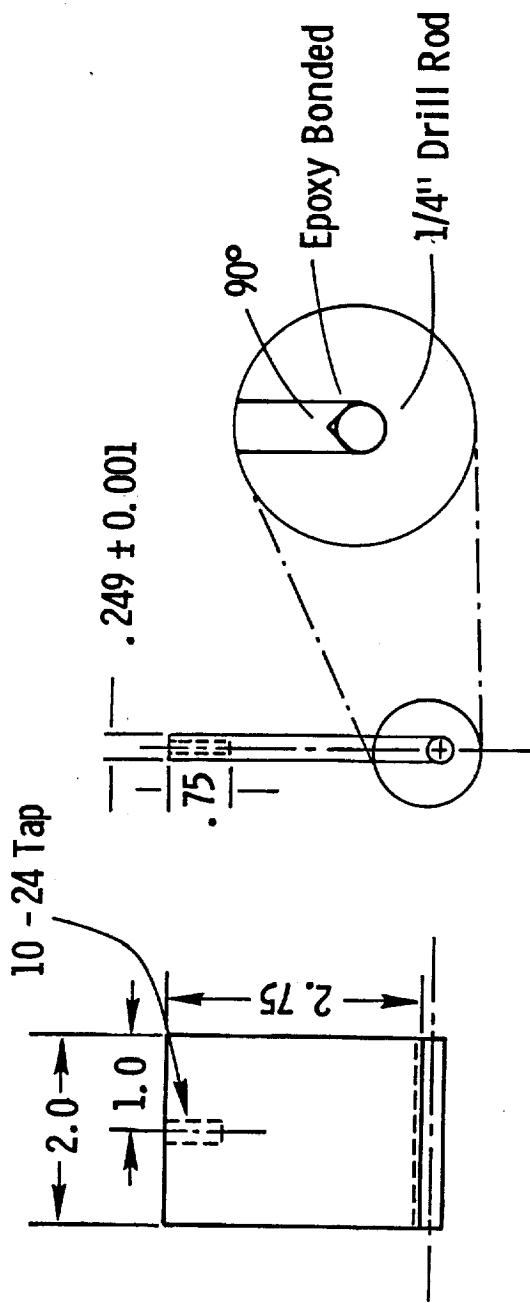


BASE

All Taps No. 10-24 (unless stated otherwise)  
 All holes drilled 0.010 oversize.  
 All lengths have tolerance of  $\pm 5$  accuracy  
 of dimension unless stated otherwise



SPECIMEN HOLDER



All lengths have tolerance of  $\pm 5$  Accuracy  
of dimension unless stated otherwise

